IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF MASSACHUSETTS

AVIDYNE CORPORATION, a Delaware corporation, Plaintiff,	)	
v.	)	Civil Action No. 05-11098 GAO
L-3 COMMUNICATIONS AVIONICS SYSTEMS, INC., f/k/a B. F. GOODRICH AVIONICS SYSTEMS, INC., a Delaware corporation, Defendant.	)	

DEFENDANT'S MARKMAN CLAIM CONSTRUCTION BRIEF

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L3 Communications Avionics Systems, Inc. ("L3") submits this construction of claims 1 and 16 of Patent No. 5,841,018 (the '018 patent; DX 1)[1] based upon the last stated interpretation of Avidyne Corporation ("Avidyne"). L3 identifies Gary S. Watson[2], inventor, and Dr. Jonathan P. How[3] in the event arguments presented by Avidyne or its expert require response.

I. THE INVENTIVE METHOD OF THE '018 PATENT

L-3 invented a unique method of compensating for the orientation of an attitude determining device as the device is installed in an aircraft. An attitude determining device is used to determine if the aircraft is flying in a level condition, or whether and to what degree the aircraft is tilted, either downward or upward or to one side. Generally speaking, the inventive method allows the attitude determining device to be mechanically installed in an aircraft's cockpit by mounting it in the aircraft's instrument panel, and then uses the operation of the device itself to internally compensate for the orientation of the device as installed in the aircraft. The device thus provides accurate attitude information regardless of orientation. Prior art techniques involved positioning the device in the aircraft's instrument panel and then shimming or otherwise adjusting the physical position of the device in order to correctly orient the device. In other words, the prior art approach was to mechanically adjust the physical orientation of the attitude determining device itself (an often difficult task due to the cramped conditions of the cockpit) in contrast to the inventive internal compensation of the device as installed.

II. BACKGROUND OF THE ISSUES

The broad scope of the '018 patent claims reflect the distinct difference between the inventive internal compensation method and the prior art physical alignment. Avidyne's

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[1] "DX ___" refers to "Defendant's Exhibit Number ___".
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[3] Address: Aerospace Controls Laboratory, Massachusetts Institute of Technology, Building 33, Room 326, 11 Massachusetts Avenue, Cambridge, Massachusetts. A copy of Dr. How's resume is attached as DX 9.

suggested interpretation may define one of several potential forms of structure and manner of internally compensating an attitude determining device encompassed by the '018 patent. However, Avidyne's litigation induced interpretation attempts to narrow the claims to a particular structure and manner of internally compensating an attitude determining device. Not only does Avidyne's suggested construction improperly limit the claims by importing unclaimed structural and functional limitations from a preferred embodiment, but it also erroneously limits the claims to a particular manner or sequential order of accomplishing internal compensation.

During prosecution, the inventors clarified for the examiner the fundamental difference between the inventive method of internally compensating the attitude determining device for installation orientation as compared to the prior art. As succinctly stated, the cited prior art:

> in no way shape or form addresses the problem of errors in installation orientation . . . [and] . . . none of the references cited . . . teach, suggest or would motivate anyone towards a method of compensating for unknown installation orientations of an attitude-determining device with respect to the reference coordinate system of a craft. (DX 4, page 2, 4-5.)

Based on this distinct difference, the first paragraph of the Summary of the Invention of the '018 patent specification summarizes the breadth of the invention:

> In accordance with the present invention, an attitude determining device which is installed onboard a mobile craft at an unknown orientation with respect to the reference coordinate system of the craft senses its installation orientation with respect to an earth frame coordinate system when the craft is at rest to obtain a static orientation measurement. An attitude of the mobile craft is measured with the attitude determining device and such measurement is compensated with the static orientation measurement to obtain attitude information of the craft's reference coordinate system with respect to the earth frame coordinate system. (DX 1, Col.1:66-Col.2:4.)[4]

In essence, the inventive method involves: installing the attitude determining device on board a craft; sensing the installation orientation of the attitude determining device relative to the craft

[4] The "018 patent (DX 1) is cited herein by "column__: lines__" as "DX1, Col.__:__"

using the device itself, and; compensating attitude measurements with the sensed installation orientation to obtain accurate attitude information of the craft relative to the earth.

The claimed method is correspondingly broad, with claim 1 essentially tracking the above quoted language of the Summary. It is important to keep in mind that the claims are method claims, not apparatus claims, and are not restricted to any structure unless expressly so limited. No structural limitations are implied regarding particular equipment within the attitude determining device used to "sense," "measure," and "compensate." Equally significantly for claim interpretation purposes, the sequential order or particular manner in which compensation of measurements by the device is accomplished is not limited by the claimed method.

Despite the significant difference between the broadly claimed method of internal compensation and the prior art approach of physically adjusting the position of the device, Avidyne improperly attempts to narrowly restrict the particular manner and sequence in which compensation is performed by importing structural and functional limitations into the claims.

III. DISCLOSURE OF THE '018 PATENT

In order to analyze the orientation of a craft, such as an aircraft, the attitude of the craft is compared to the earth. An imaginary coordinate system is assumed to reside on the craft.

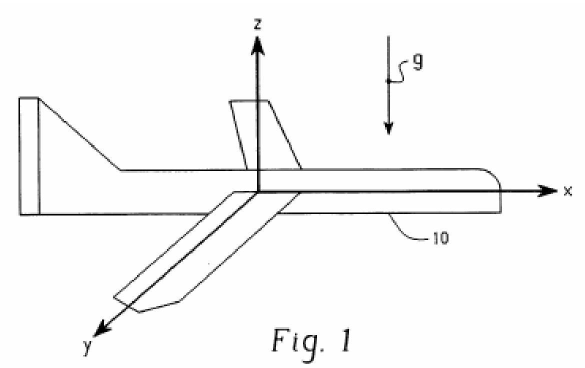

Fig. 1

As shown in Figure 1 (DX 1), the preferred coordinate system has three axes at right angles (x, y, and z axis) that stay with the craft regardless of the craft's orientation. A coordinate system is

assumed for the earth, which is based on the direction of gravity (g) acting as the vertical z axis of the earth based coordinates. The attitude of the craft is determined by comparing the aircraft's coordinate system to the earth's coordinate system.

As shown in Figure 3, an attitude determining device 20 is mounted in a craft 10 (DX 1).

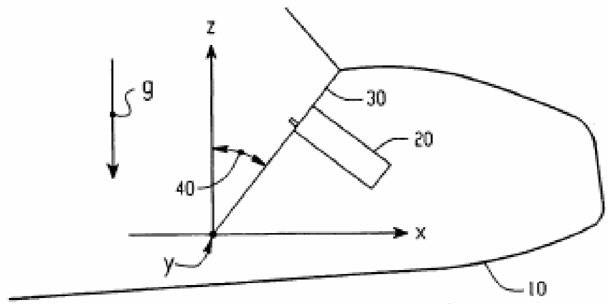

Fig. 3

Although the device 20 may be mounted to an instrument panel 30 that is at a set angle 40, the actual orientation of the attitude determining device 20 is not precisely known due to manufacturing deviations and the like (DX 1, Col. 3:52-56).

Several versions of attitude determining device are disclosed. The patent discloses that the device may be one which has internal components that are fixed in place within the outer case, referred to as a "strap down" system. (DX 1, Col. 3:41-43.) The patent discloses alternatively that the device may have internal components that are free to rotate. The mounting that allows internal components to rotate is called a gimbal. (DX 1, Col. 3:43-45.) Laypeople may be familiar with such a rotating gimbaled device called a gyroscope or gyro. (See DX 2, pages 851 and 892: definitions of gimbal, gimbaled inertial system, and gyroscope.)

In one embodiment the attitude determining device 20 has acceleration sensors that, when the craft is at rest, sense acceleration (α) that results from gravity acting along the three axis (see block 50 shown in Figure 5 as follows). (DX 1, Col. 3:19-31, Col. 4:12-20, Col. 4:37-42.) In that embodiment, the device includes a processor 52, essentially a computer, which calculates

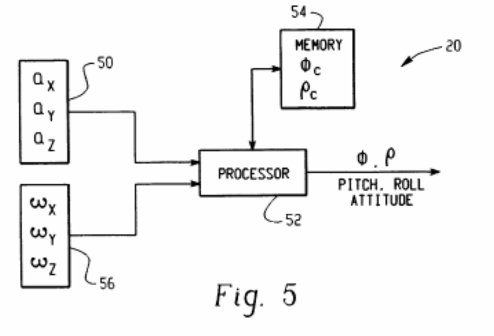

Fig. 5

the angle along each of these axes that corresponds to the sensed acceleration. (DX 1, Col. 3:19-31; 3:35-40; 4:10-23; 4:37-45.) Rate sensors 50 measure rotation around the three axes as the craft moves. In an alternative embodiment the attitude determining device 20 includes level sensors that sense the angles along the three axes. (DX 1, Col. 5:6-21.)

The attitude determining device is used to sense information for determining the position of the device itself while the craft is at rest. (DX 1, Col. 1:66-2:4.) The patent discloses several embodiments of how to accomplish this at rest determination, referred to as the "static orientation measurement." In one disclosed approach the craft is initially leveled as shown previously in Figure 1. When the craft is leveled the attitude determining device is used to sense and determine the orientation of the device and thus arrive at the static orientation measurement along the three axes. (DX 1, Col. 3:11-17, Col. 4:37-45, Col. 4:59-63.) In another disclosed approach the craft is not leveled prior to proceeding with the inventive steps, but left unleveled as shown in Figure 7 that follows. (DX 1, Col. 5:21-29.)

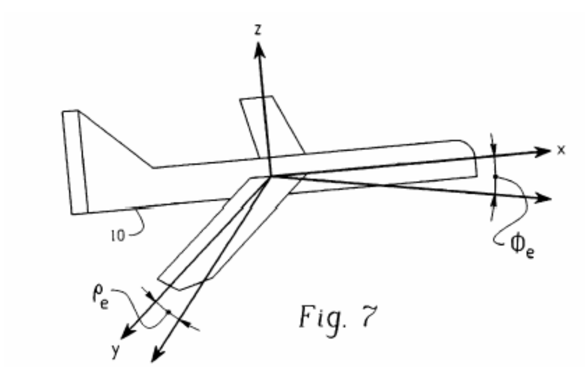

Fig. 7

The amount of deviation from level is measured for the axes. These measured deviations are input into the processor 52 which then calculates the at rest orientation of the device given the accelerations sensed by the device and the input deviations. (DX 1, Col. 5:21-44.)

Regardless of how the static orientation measurement is determined, in the preferred embodiment the static orientation measurement is stored for use in compensating the measurements determined by the attitude determining device. Again, several embodiments of this storage are disclosed. In one embodiment the installation orientation information is stored in non-volatile memory of the attitude determining device and is therefore available each time the device is turned on. (DX 1, Col. 4:10-12, Col. 4:63-5:8.) In another disclosed embodiment the attitude determining device does not include non-volatile memory, and the sensing of the installation orientation information must be undertaken each time power to the unit is turned on and then stored in the device's memory. (DX 1, Col. 5:45-50.)

IV. PROSECUTION OF THE '018 PATENT

During prosecution of the '018 patent in the Patent Office, no claim amendments were made. The inventors argued that the cited prior art did not even address the issue of compensating for installation errors of an attitude determining device. No arguments were made that would restrict the scope of the claims, and in fact it was acknowledged that the claims had broad scope and that there is no set sequence for the measuring and compensating operation.

Application Serial No. 08/785,553, which led to the issuance of the '018 patent, was filed with twenty claims identical to those which issued in the patent. The patent examiner initially entered an office action (DX 3) that rejected claims 1-3, 6, and 9-20 as obvious under 35 USC §103(a) over combinations of three prior art patents. However, the examiner found that dependant claims 4, 5, 7, and 8 defined patentable subject matter. The examiner's statement as

follows that dependant claims were patentable due to inclusion of the "particular compensation method" establishes the examiner did not interpret the independent claims to be restricted to the "particular compensation method:"

> The subject matters of claims 4-5 and 7-8 are deemed to be patentable because the prior art fail to disclose and/or make obvious the claimed particular compensation method. Major emphasis is being placed upon the provision of "Determination of static attitude pitch" as a "trigonometric function of a ratio" of acceleration components wherein the "orientation measurement" comprises the "static attitude pitch" and "static attitude roll" in combination with remaining limitations of theses [sic] claims and their dependent ones. (DX 3, page 4.)

The inventors responded in a document (DX 4) titled "Amendment", but which did not include any amendment of the claims, only discussion. In that response it was explained that none of the cited prior art addressed the problem addressed by the invention, i.e. errors in installation of the attitude determining device:

> Achkar [prior art patent] in no way shape or form *addresses the problem of errors in installation orientation* and thus, would have no reason or motivation to compensate for such errors in installation.
> Further, the Examiner acknowledges that Achkar does not explicitly recite the utilization of sensing the installation orientation (*This is because the problem of errors in installation orientation is not addressed.*) (DX 4, page 2; emphasis added.)

> None of the cited [prior art] references Achkar, McMurtry or Duncan either taken individually or in combination teach, suggest or would motivate anyone to sense an unknown installation orientation of an attitude determining device, and compensate the craft attitude measurement of the device with the static orientation measurement to obtain attitude information of the crafts' reference coordinate system with respect to the earth frame coordinate system. *In fact none of the references even address the issue of errors in installation orientation.* (DX 4, page 5; emphasis added.)

The inventors confirmed that there was no sequence to the operations of measuring and compensating and in fact characterized those operations as a single "step":

> ***Independent claims 1 and 16 recite, in substance, a method*** of compensating for installation orientation of an attitude determining device on board a mobile craft ***comprising the steps of*** 1) installing the attitude determining device at an <u>unknown</u> orientation with respect to the reference coordinate system of the craft, 2) sensing the installation orientation while the craft is at rest to obtain a static orientation

> measurement of the device, ***and 3) compensating the craft attitude measurement of the device with the static orientation measurement.*** (DX 4, Page 3; italics added.)

All of the application claims were allowed in the next action without further rejection or argument, and the examiner stated his reasons for allowance. (DX 5, page LC03393-94.) In so doing, no importance was attributed to the sequence of compensating and measuring:

> ***Reasons for Allowance***
>
> 1. The following is an Examiner's Statement of Reasons for Allowance: The primary reason for allowance of the claims is that prior art neither teach nor fairly suggest the particular combinations of the method of compensating for installation orientation of an attitude sensor as appears in method claims 1 and 16. Major emphasis is being placed upon the provision of an 'installing' an 'altitude [sic] determination device' at an 'unknown orientation' and 'compensating' the result with a 'static orientation measurement' in combination with other limitations of the said independent claim, and its dependent ones.

V. CLAIM CONSTRUCTION LAW

Claim interpretation is a matter of law. *Markman v. Westview Instruments Inc.*, 52 F.3d 967, 979 (Fed. Cir. 1995), *aff'd.*, 517 U.S. 370 (1996). In claim interpretation, the court should look first to the intrinsic evidence, *i.e.*, the patent itself, including the claims, specification, and prosecution history. Such intrinsic evidence is the most significant source of the legally operative meaning of disputed claim language. *Bell Atlantic Network Services, Inc. v. Covad Communications Group, Inc.*, 262 F.3d 1258, 1267 (Fed. Cir. 2001).

The words of the claims are the most important feature of claim scope. *Karlin Technology Inc. v. Surgical Dynamics Inc.*, 177 F.3d 968, 971 (Fed. Cir. 1999); *Bell Communications Research, Inc. v. Vitalink Communications Corp.*, 55 F.3d 615, 619-20 (Fed. Cir. 1995). The court is to determine what a person of ordinary skill in the art would understand the claims to mean. *Vanderlande Industries Nederland BV v. ITC*, 366 F.3d 1311, 1318 (Fed. Cir. 2004); *Bell Atlantic*, 262 F.3d at 1267. Extrinsic evidence can, therefore, shed useful light on the relevant art and better allow a court to place itself in the shoes of a person of ordinary skill

in the art. *Vanderlande*, 366 F.3d at 1318. Extrinsic evidence includes evidence such as dictionaries, expert testimony, articles, and inventor testimony. *Bell Atlantic*, 262 F.3d at 1269.

The patent "specification" must include a written description of the preferred embodiment of the invention. Although the specification may aid in interpreting the meaning of disputed claim language, particular embodiments appearing in the specification will not generally be read into the claims. *Constant v. Advanced Micro-Devices, Inc.*, 848 F.2d 1560, 1571 (Fed. Cir.), *cert.denied*, 488 U.S. 892 (1988). In other words, disclosure of a narrower embodiment in the specification will not operate to narrow the claims. *CCS Fitness Inc. v. Brunswick Corp.*, 288 F.3d 1359, 1367 (Fed. Cir. 2002); *Laitram Corp. v. NEC Corp.*, 163 F.3d 1342, 1347-48 (Fed. Cir. 1998).

The doctrine of "claim differentiation" may have relevance in this action. Under that doctrine, if a dependent claim adds a limitation, the prior independent claim may not be interpreted as restricted to the dependent claim's added limitation. *E.g., Karlin Tech., Inc.*, 177 F.3d at 972; *Wenger Mfg., Inc. v. Coating Machinery Systems Inc.*, 239 F.3d 1225, 1234 (Fed. Cir. 2001). In other words, a dependent claim limitation may not be read into the independent claim or the dependent claim would be superfluous. Claim differentiation may be used for interpretation purposes even if consideration is given to dependant claims not asserted or in issue. See e.g. *Fromson v. Advance Offset Plate, Inc.*, 720 F.2d 1565, 1570 (Fed. Cir. 1983).

It is important to keep in mind that a claim must be read as a whole, rather than element by element. *In re Gulack*, 703 F.2d 1381, 1385 (Fed. Cir. 1983) (noted as a "basic principle of claim interpretation"). Although in some instances in the discussion that follows the parties have approached the interpretation of the claims on the basis of individual elements, the element under scrutiny must be considered in the context of the claim overall.

VI. INDEPENDENT CLAIMS 1 & 16

A chart comparing the parties' interpretations with the language of claims 1 and 16 is attached as Exhibit DX 8. The disputed terms of Claim 1 are emphasized as follows:

> 1. A method of **compensating for installation orientation of an attitude determining device** on-board a mobile craft with respect to a reference coordinate system of said craft to obtain attitude information of said craft from said device based on an earth frame coordinate system, said method comprising the steps of:
> installing said **attitude determining device** on-board said mobile craft at an unknown orientation with respect to said reference coordinate system of said craft;
> **sensing the installation orientation of said attitude determining device with respect to said earth frame coordinate system when said craft is at rest to obtain a static orientation measurement of said device**;
> **measuring an attitude of said mobile craft with said attitude determining device**; and
> **compensating said craft attitude measurement of said device with said static orientation measurement to obtain attitude information of said craft's reference coordinate system with respect to said earth frame coordinate system**.

The disputed terms of Claim 16 are emphasized as follows:

> 16. A method of **compensating for installation orientation of an attitude determining device** on-board a mobile craft with respect to a reference coordinate system of said craft to obtain attitude information of said craft from said device based on an earth frame coordinate system, said method comprising the steps of:
> installing said **attitude determining device** on-board said mobile craft at an unknown orientation with respect to said reference coordinate system of said craft;
> **sensing the installation orientation of said attitude determining device with respect to said earth frame coordinate system when said craft is at rest to obtain a static orientation measurement of said device**;
> **storing said static orientation measurement in a memory**;
> **measuring an attitude of said mobile craft with said attitude determining device**;
> **retrieving said static orientation measurement from said**

memory to a processor of said device; and
compensating said craft attitude measurement with said retrieved static orientation measurement in said processor to obtain attitude information of said craft's reference coordinate system with respect to said earth frame coordinate system.

The disputed terms of claim 1 are first addressed, of which all but the last "compensating" clause also appears in claim 16, followed by the disputed terms of claim 16 not previously discussed.

A. Attitude Determining Device (Claims 1 and 16)

The claim requirement of "attitude determining device" is interpreted as "a piece of equipment that determines angular orientation relative to the earth frame and is used to establish the attitude of a craft."

The term "attitude determining device" as appears in claims 1 and 16 is to be broadly interpreted. Avidyne attempts to narrow this term by suggesting the device (1) should be limited to include a structural element of the preferred embodiment discussed in the specification, a processor, and (2) should also be limited to require the incorporation of two structural elements, a gravity sensor and a motion sensor, which names do not appear in the patent but which Avidyne assigns to the functional operation of sensors discussed in the preferred embodiments. Avidyne suggests an "attitude determining device" be limited to "a device that includes gravity and motion sensors and a processor for processing the output of the sensors to determine attitude." (Emphasis added.) Avidyne's approach is an ill-concealed effort to improperly import claim limitations from the Description of the Preferred Embodiment and restrict the claims to such an embodiment. The claims themselves are therefore first addressed.

The Claims. Both independent claim 1 and 16 include reference to an "attitude determining device." That term, in and of itself, does not refer to a "processor." Contrary to Avidyne's argument, claim 1 nowhere references a "processor." Likewise none of the claims dependant on claim 1 makes reference to a processor. These other claims, both asserted and

unasserted, may be considered in this analysis. *Vitronics Corp. v. Conceptronic, Inc.*, 90 F.3d 1576, 1582 (Fed. Cir. 1996). Unlike claim 1, claim 16 does reference "a processor." It is clear that when the inventors wanted to include the requirement of a "processor" in a claim they knew how to do this: the word processor was used. When a claim was not to be so restricted, the claim makes no reference to a processor.

If claim language is clear on its face, then the rest of the intrinsic evidence is restricted to determining whether a deviation from the clear language of the claims is specified. *Interactive Gift Exp. Inc. v. Compuserve Inc.,* 256 F.3d 1323, 1331 (Fed. Cir. 2001). Method claims are not to be restricted to particular structure absent an express requirement in the claim. *E.g. Gottshalk* v. *Benson*, 409 U.S 63, 70-71, 93 S.Ct. 253, 256 (1972). Neither claim 1 nor claim 16 reference a "gravity sensor" or a "motion sensor." Likewise, neither is referenced in the dependant claims. Of course, some dependant claims do reference different types of sensors, such as "acceleration sensors" (claim 18) and "level sensors" (claim 19). The doctrine of claim differentiation, however, precludes the sensing step of broad independent claims 1 and 16 to be limited to these particular sensors. *Karlin Tech,* 177 F.3d at 972; *Wenger,* 239 F.3d at 1234.

Of course, L3 would agree with Avidyne that an attitude determining device performs the act of sensing. The claims themselves establish this. There is no basis, however, for incorporating specific structures from the preferred embodiment, i.e. a processor and two particular sensors, particularly when Avidyne generates names for these structures that do not appear in the '018 patent or its prosecution.

The Specification. The'018 patent specification broadly describes attitude determining devices without limitation to any particular structure. The Background of the Invention broadly defines attitude determining devices in terms of function of the "device" overall, without

mention of a "processor" or "sensors:"

> *Attitude determining devices* for mobile craft, like aircraft, for example, measure the attitude of the moving craft with respect to an outside reference coordinate system, typically known as earth frame. (DX 1, Col. 1:15-18; emphasis added.)
>
> * * *
>
> Conventionally, aircraft *attitude determining devices* primarily measure attitude of the aircraft in pitch and roll. (DX 1, Col. 1:29–31; emphasis added.)

The Summary of the Invention also discusses the attitude determining device in broad terms keyed to the function of the "device," but likewise the Summary of the Invention nowhere references a processor or sensors. For example:

> In accordance with the present invention, an *attitude determining device* which is installed onboard a mobile craft at an unknown orientation with respect to the reference coordinate system of the craft senses its installation orientation with respect to an earth frame coordinate system when the craft is at rest to obtain a static orientation measurement. (DX 1, Col. 1:66- Col. 2:4; emphasis added.)
>
> * * *
>
> In one embodiment, the acceleration of the *attitude determining device* is sensed for each of the axes of the reference coordinate system of the mobile craft while at rest and leveled, and a static attitude pitch and static attitude roll of the device are determined from trigonometric functions of ratios of the sensed accelerations. Accordingly, both of the measured attitude pitch and roll of the device are compensated with the static attitude pitch and the static attitude roll, respectively, in the *attitude determining device* … (DX 1, Col. 2:10-18; emphasis added.)

The Abstract is similarly devoid of reference to a processor or sensors. (DX 1, page 1.)

The Summary does establish that the attitude determining device "senses its installation orientation," but that is a reference to an operation performed by the device overall. There is no restriction or even discussion in the Summary of particular subcomponents used to perform this sensing, such as particular sensors or a processor. Likewise, the second paragraph of the Summary describes an embodiment sensing acceleration, but again this function is ascribed to the attitude determining device without restriction to a particular subcomponent. There is no basis to break the "attitude determining device" into subcomponents, particularly since the claim

language only specifies that "sensing" be performed by the device overall.

The Description of the Preferred Embodiment includes numerous references to attitude determining devices. That description references a "processor 52," but the description by definition only relates to the "Preferred Embodiment." *E.g. Rexnord Corp. v. Laitram Corp.*, 274 F.3d 1336, 1344-45 (Fed. Cir. 2001). Drawing Figures 5 and 6 schematically depict a processor 52, but the Brief Description of the Drawings references those figures as "a suitable embodiment" of the device and "an alternative embodiment," respectively.

The specification uses neither the term "gravity sensor" nor "motion sensor." The specification makes various reference to the attitude determining device performing sensing and discloses preferred embodiments of sensors, but there are no words of clear limitation or disavowal of scope that mandate the restriction to a set of "gravity and motion sensors."

The Description of the Preferred Embodiment discloses that embodiments of the attitude determining device "may include" acceleration sensors (e.g. DX 1, Col. 3:19-21), and recognizes that acceleration sensors may determine the gravity vector (DX 1, Col. 3:26-28). Numerous other versions of sensors are disclosed, such as level sensors as an alternative to acceleration sensors (DX 1, Col. 5:7-10), and rate sensors to measure rotational motion (DX 1, Col. 3:21-31). The attitude determining device is disclosed as varying from a device that is the strap down type to a "gimballed instrument having elements which are free to rotate in inertial space" (DX 1, Col. 3:41-44.) The Description recognizes that in embodiments which use a gimbaled attitude determining device the angles of the spin axis may be "measured using synchros or other such devices." (DX 1, Col. 4:54-56.) There is no proper basis for transporting structural elements into the claims under the guise of interpretation.

<u>**Prosecution History.**</u> While the prosecution history can also provide evidence of the

meaning of the specific terms used in the claims, unless the prosecution history is unequivocal or contains a clear disavowal of an interpretation urged by the patentee, it may not be used to alter the meaning of a claim derived from the claim wording and specification. *Serrano v. Telular Corp.*, 111 F.3d 1578, 1584 (Fed. Cir. 1997); *Standard Oil Co. v. American Cyanamid Co.*, 774 F.2d 448, 452 (Fed. Cir. 1985). Nothing in the prosecution history, whether by way of amendment to the claims or by way of argument to the examiner, restricts the interpretation of "attitude determining device" to a device that includes a processor or a device that includes gravity and motion sensors. The inventors did not argue the difference between the prior art and the claimed attitude determining device was a processor or gravity and motion sensors.

The approach for considering claim terms in light of the specification is straightforward. If claim terms of broad scope are used the terms are to be interpreted broadly unless the specification or the prosecution history include language evidencing a clear disavowal of claim scope. As ruled in *Teleflex, Inc. v. Ficosa N. Am. Corp.*, 299 F.3d 1313, 1327 (Fed. Cir. 2002):

> We hold that claim terms take on their ordinary and accustomed meanings unless the patentee demonstrated an intent to deviate from the ordinary and accustomed meaning of a claim term by redefining the term or by characterizing the invention in the intrinsic record *using words or expressions of manifest exclusion or restriction, representing a clear disavowal of claim scope*. (Emphasis added.)

There is no such disavowal here.

Avidyne engages in the classic error of attempting to read limitations from the preferred embodiment into the claim. This is improper. See *Teleflex v. Ficosa*, 299 F.3d at 1328 ("We 'have cautioned against limiting the claimed invention to preferred embodiments or specific examples in the specification.'" (citations omitted.) It is understood that the claim term "attitude determining device" does not exclude the inclusion of a processor or the various sensors that are discussed relative to the disclosed embodiments. See *Burke, Inc. v. Bruno Independent Living*

Aids, Inc., 183 F.3d 1334, 1341 (Fed. Cir. 1999). Rather, the claim term is to be interpreted broadly enough to encompass a device with these elements, but is not limited to these elements. L3's definition is consistent with the broad definition keyed to the function of the "device" as provided by the Background and Summary of the Invention, rather than specific examples mentioned in the Description of the Preferred Embodiment.

B. Compensating for Installation Orientation of an Attitude Determining Device (Claims 1 and 16):

The claim requirement of "compensating for installation orientation of an attitude determining device" is interpreted as "adjusting to neutralize the effect of the orientation of an attitude determining device as installed."

Avidyne suggests this clause does not even require interpretation. This requirement is included at the beginning of both independent claim 1 and 16, and breathes life and meaning into the claims. This clause establishes that the subsequent steps are not a series of indiscriminant requirements, but rather a collective method that accomplishes a goal. See *Griffin v. Bertina*, 285 F.3d 1029, 1033 (Fed. Cir. 2002) (Performing the listed steps alone "are merely academic exercises. The preamble is thus a necessary limitation.") This clause was a basis argued during the patent prosecution to distinguish the claims over the prior art. As such the preamble is an element of the claim. *E.g. In re Cruciferous Sprout Litigation*, 301 F.3d 1343, 1347 (Fed. Cir. 2002); *General Electric Co. v. Nintendo Co.*, 179 F.3d 1350, 1361 (Fed. Cir. 1999).

The Claims. Both of the independent claims include this requirement of "compensating for installation orientation of an attitude determining device." In the preamble the clause "compensating" is not stated as the act of compensating one measurement with another measurement. Instead, the first use of "compensating" in the claims is to address the "installation orientation" of an attitude determining device. In this instance the ordinary meaning of the term "compensate" is consistent with the structure of the claim language itself.

The ordinary meaning of "compensating" is to counterbalance, counteract or neutralize:

> *vt* 1: to be equivalent to: counterbalance …3 a: to provide with means of counteracting variation b: to neutralize the effect of (variations); *N vi* 1: to supply an equivalent – used with *for* 2: To offset an error, defect or undesired effect. *Merriam Webster's Collegiate Dictionary*, page 234 (10th Ed. 1995). (DX 6.)

> 1. To offset; counterbalance. . . 3. To stabilize the purchasing power of (a monetary unit) by changing the gold content in order to counterbalance price variations. *–intr*. To serve as or provide a substitute or counterbalance. . . *The American Heritage Dictionary*, page 385 (3rd Ed. 1992). (DX 7.)

The claims set out a method to neutralize or counteract the effect of the installation of the attitude determining device. In this instance, since multiple definitions of "compensate" are applicable to the claim and consistent with the use of the word as appearing in the intrinsic patent record, the term throughout the claim is to be construed to encompass all consistent meanings. *Brookhill-Wilk 1, LLC v. Intuitive Surgical, Inc.*, 334 F.3d 1294, 1300 (Fed. Cir. 2003).

Each of the independent claims also includes a "compensating" step in the closing clause of the claim. A claim term is to be interpreted consistently with its appearance elsewhere in the same claim or in other claims of the same patent. *Rexnord Corp. v. Laitram Corp.*, 274 F.3d 1336, 1342 (Fed. Cir. 2001). As hereinafter discussed relative to the subsequent "compensating" clauses, this interpretation of "compensating" is consistent throughout the claims.

L3 recognizes that general purpose dictionaries cannot supplant the meaning of a term as reflected by consideration of the patent specification. *W.E. Hall Co. v. Atlanta Corrugating, LLC*, 370 f.3d 1343, 1350 (Fed. Cir. 2004); *Vanderlande Industries Nederland BV v. ITC*, 366 F.3d 1311, 1321 (Fed. Cir. 2004). When a claim term has an ordinary meaning consistent with the specification, however, it is error to deviate from that ordinary meaning in order to restrict the claim term absent a clear directive in the specification to do so. *E.g. Bell Atlantic Network*

Servs., Inc. v. Covad Communications Group, Inc., 262 F.3d 1258, 1267 (Fed. Cir. 2001); *Constant v. Advanced Micro-Devices, Inc.*, 848 F.2d 1560, 1571 (Fed. Cir. 1988).

The Specification. The Background discusses the problem addressed by the invention:

> Any inaccuracy in installing an attitude determining device in the craft with respect to the reference coordinate system thereof will result in inaccurate measurement and presentation of the attitude of the craft to either the pilot or other system using the attitude information for display or control purposes. (DX 1, Col.1:32-37.)

The Background discusses the prior art methods of mechanically adjusting the physical position of the attitude determining device itself and the difficulties with such methods. (DX 1, Col. 1:37-49.) The Background concludes with the recognition that the invention of the '018 patent solves the problem of inaccuracy in installation of the attitude determining device:

> Accordingly, the inventive method described herein below ensures a substantially accurate measurement of aircraft attitude by the attitude determining device with respect to the earth frame of reference. (DX 1, Col. 1:56-59.)

The Summary of the Invention starts with a paragraph prefaced as "In accordance with the present invention," (DX 1, Col. 1:66.) The Summary subsequently includes paragraphs stated to be specific to particular embodiments, i.e. "In one embodiment," (DX 1, Col. 2:10) and "In another embodiment," (DX 1, Col. 2:21). That initial paragraph of the Summary of the Invention tracks broad claim 1 and specifies that the attitude determining device senses its installation orientation and a measured attitude is compensated with the static orientation measurement, but there is no limitation of the particular function used for that compensation. (DX 1, Col. 1:66-2:9). The Summary clearly distinguishes between the initial, more generic, description of the invention and the subsequent descriptions of particular embodiments. Importantly, there is no restriction of the mechanism by which the compensation occurs.

The Description of the Preferred Embodiment discussed a number of embodiments. That Description of the Preferred Embodiment again sets out the nature of the installation problem to be solved, which is to provide accurate attitude information by compensating for the orientation of the attitude determining device as installed. (DX 1, Col. 3:60–Col. 4:2.) In the cited passage there is no discussion of compensating one measurement with another measurement, but simply of compensating for the installation orientation of the attitude determining device.

The Prosecution History. The prosecution history is likewise consistent with L3's interpretation and does not restrict the interpretation of "compensating." To the contrary, the prosecution history establishes that the interpretation of "compensating" is to neutralize errors in installation of the attitude determining device.

In responding to the only rejection issued during prosecution, the inventors did not reference a particular compensation method. Rather, the inventors noted the breadth of the independent claims and that the compensation method was to address the installation orientation of the attitude determining device:

> Independent claims 1 and 16 *recite, in substance, a method of compensating for installation orientation of an attitude determining device* on board a mobile craft comprising the steps of 1) installing the attitude determining device at an unknown orientation with respect to the reference coordinate system of the craft, 2) sensing the installation orientation while the craft is at rest to obtain a static orientation measurement of the device, and 3) compensating the craft attitude measurement of the device with the static orientation measurement.
> (DX 4, page 3; italics added.)

The only argument presented was the repeated clarification that the prior art "in no way shape or form addresses the problem of errors in installation orientation." (DX 4, page 2.) "Therefore, none of the references cited against the claims, taken individually or in combination, teach, suggest or would motivate anyone towards a method of compensating for unknown installation orientations of an attitude-determining device with respect to the reference

coordinate system of a craft." (DX 4, page 4 – 5.) "In fact, none of the references even address the issue of errors in installation orientation." (DX 4, page 5.) The use of the preamble requirement to distinguish the prior art during prosecution establishes that this is an element of the invention. *E.g. Invitrogen Corp. v. Biocrest Mfg., L.P.*, 327 F.3d 1364, 1370 (Fed. Cir. 2003); *In re Cruciferous Sprout Litigation*, 301 F.3d 1343, 1347 (Fed. Cir. 2002).

C. Sensing the Installation Orientation of Said Attitude Determining Device with Respect to Said Earth Frame Coordinate System When Said Craft is at Rest to Obtain a Static Orientation Measurement of Said Device (Claims 1 and 16):

The claim requirement of "sensing the installation orientation of said attitude determining device with respect to said earth frame coordinate system when said craft is at rest to obtain a static orientation measurement of said device" is interpreted as "detecting an angular orientation with the installed attitude determining device relative to earth frame while the craft is not moving to obtain a static orientation measurement of said device."

The difference Avidyne suggests from this interpretation is "detecting <u>the angular position of</u> the installed attitude determining device" rather than L-3's proposed "detecting <u>an angular orientation with</u> the attitude determining device." The remainder of the interpretations espoused by the parties is the same. Avidyne's interpretation is erroneous in two regards, it would allow the sensing step to be performed by some other device without use of the attitude determining device, and promote juror confusion that the detected value be one specific location (position) within the craft rather than a relative orientation.

<u>The Claims.</u> The claims reference a sensing that closes with "to obtain a static orientation measurement of said device." This reflects that it is a measurement of the device, i.e. performed by the device, which is being obtained. This is consistent with the specification. Nowhere do the claims reference "position." That term connotes a location. All of the claims consistently use the term "orientation," which has no connotation of a specific location.

<u>The Specification.</u> The Abstract specifies that it is the attitude determining device that

performs the sensing when the craft is at rest to obtain a static orientation measurement:

> In accordance with the disclosed method, an attitude determining device…**<u>senses its</u>** installation orientation with respect to an earth frame coordinate system when the craft is at rest to obtain a static orientation measurement thereof.
> (DX 1, cover; emphasis added.)

The Background of the Invention likewise references that the sensing is performed by the attitude determining device itself:

> The static installation orientation is automatically determined **<u>by the device itself</u>** and the attitude measurement is compensated therewith in a processor of the device. (DX 1, Col. 1:59 – 62; emphasis added.)

The Summary of the Invention section commences with a statement addressed to the invention itself, rather than to a preferred embodiment, and directs that it is the attitude determining device that senses its own installation orientation:

> In accordance with the present invention, an attitude determining device which is installed onboard a mobile craft at an unknown orientation with respect to the reference coordinate system of the craft **<u>senses its</u>** installation orientation with respect to an earth frame coordinate system when the craft is at rest to obtain a static orientation measurement. (DX 1, Col. 1:66-Col. 2:4; emphasis added.)

The subsequent paragraphs of the Summary are directed to "one embodiment" and "another embodiment" respectively. The statements of the first paragraph are important, in that they reflect the inventors' explanation of the invention itself as compared to an embodiment. See *Microsoft Corp. v. Multi-Tech Systems, Inc.*, 357 F.3d 1340, 1347-48 (Fed. Cir. 2004); *Watts v. XL Sys., Inc.*, 232 F.3d 877, 882-82 (Fed. Cir. 2000). Indeed, the first paragraph of the Summary generally tracks independent claim 1.

The Description of the Preferred Embodiment discusses various preferred embodiments and establishes that the sensing is undertaken by the attitude determining device. (DX 1, Col. 3:19 – 40; Col. 4:7-15; Col. 4:59-65; Col. 5:7-18; Col. 5:32-24.) In each embodiment a sensing is undertaken by the attitude determining device, even if additional information is also provided.

Although the Description of the Preferred Embodiment is not in of itself limiting, it is consistent with the Summary's first paragraph, the Abstract and Background.

The specification consistently uses the term "orientation" with regard to the attitude determining device. The specification nowhere references the "position" of the device. The Background does state the attitude determining device may be installed "at a location in the craft in such a manner to be mechanically aligned with the reference coordinate system of the craft." (DX 1, Col. 1:18-21.) In that passage the "location" in the craft would correspond to the "position" of the device. That passage's reference to "in such manner to be mechanically aligned with…" corresponds to the "orientation" of the device. The word "position" would carry with it the implication of a particular location within the craft, which is not a correct interpretation.

The Prosecution History. During prosecution the inventors argued that the prior art did not even contemplate the problem of installation error of an attitude determining device.

Collectively the claims, specification and prosecution establish that the "sensing" step is to be undertaken using the attitude determining device itself. Likewise, the proper term for interpretation with regard to the attitude determining device is orientation, not position.

D. Measuring an Attitude of Said Mobile Craft with Said Attitude Determining Device (Claims 1 and 16):

The claim requirement of "measuring an attitude of said mobile craft with said attitude determining device" is interpreted as "using the attitude determining device to measure an angular orientation of the mobile craft."

Avidyne attempts to narrow this interpretation by arguing that measuring (1) is limited to the verb "to process," (2) by a device constructed in accordance with Avidyne's improperly narrowed definition to incorporate a "processor" and "sensors," and (3) must include the further limitation "to obtain the uncompensated attitude measurement," which limitation appears nowhere in the claims or prosecution history of the '018 patent. It is Avidyne's belief that

"measuring an attitude of said mobile craft with said attitude determining device" requires "using the **processor** of the attitude determining device **to process** the output of the **sensors** of the attitude determining device, **to obtain** the **uncompensated attitude** of the mobile craft." (Emphasis added.) L3's interpretation is consistent with the '018 patent claims and disclosure, while Avidyne only seeks to improperly introduce limitations in efforts to avoid infringement.

The Claims. Both independent claims 1 and 16 include the phrase "measuring an attitude of said mobile craft with said attitude determining device." Wholly absent from this phrase is reference to the structural limitations of a processor or sensors, or the limitation "to obtain the uncompensated attitude measurement." This claim requirement does not specify any result of the requirement, let alone the "obtaining" limitation manufactured by Avidyne.

Notably, both claims 1 and 16 include "to obtain" in their preambles and in two other clauses to indicate a result obtained by those clauses. The preambles of claims 1 and 16 provide:

> a method of compensating . . . *to obtain* attitude information of said craft from said device based on an earth frame coordinate system.

The "sensing" clauses of claims 1 and 16 both specify:

> sensing . . . *to obtain* a static orientation measurement of said device.

Similarly, the "compensating" clauses of claims 1 and 16, both specify:

> compensating . . . *to obtain* attitude information of said craft's reference coordinate system with respect to said earth frame coordinate system.

Clearly, the inventors knew how to indicate the obtaining of a specified result by use of "to obtain" in a claim, but did not include a "to obtain" term in the measurement requirement.

The resultant "uncompensated attitude measurement" added by Avidyne does not appear in <u>any</u> of the claims of the '018 patent. Avidyne's suggested limitation that "measuring an attitude of said mobile craft with said attitude determining device" must be done "to obtain

uncompensated attitude measurement" is an improper attempt to narrow the functional performance of the claimed inventive method. *Transmatic Inc v. Gulton Industries Inc.*, 53 F.3d 1270, 1278 (Fed. Cir. 1995)(reversing interpretation for "importing unnecessary functional limitations into the claim" offered by the accused infringer in what "appears to be a litigation-induced interpretation to avoid infringement").

Not only does Avidyne's proposed construction for the "measuring" clause add a non-existent functional limitation, it also improperly narrows the act of "measuring" to "using the processor . . . to process output of the sensors." Nowhere do the claims of the '018 patent recite that "measuring" is limited to using a "processor . . . to process output of the sensors." Claim 1 references neither a processor nor sensors. Claim 1 likewise does not reference "output" of sensors, or the processing of output. Although claim 16 may reference a processor in another clause there is no reference to sensors or output of sensors. Various sensors do, however, appear in the dependant claims. The claims make clear that the inventors knew how to include the requirement of a "processor" and some form of a "sensor" by their inclusion in other claims or claim limitations. Thus, these limitations cannot properly be imported into this phrase.

Finally, Avidyne attempts to improperly add a new limitation of an "uncompensated" attitude measurement. Not only is it improper to read limitations into the claims, but in this instance Avidyne itself creates this "uncompensated" limitation, which term appears nowhere in the patent. Avidyne's error is driven by its desire to restrict the claims to a specific sequence or order of steps. With method claims it is fundamental, however, that unless the steps of the method actually recite an order, the steps are not ordinarily construed to require one. *E.g. Moba, B.V. v. Diamond Automation, Inc.*, 325 F.3d 1306, 1313-14 (Fed. Cir. 2003); *Interactive Gift Express, Inc. v. Compuserve Inc.*, 256 F.3d 1323, 1342-43 (Fed. Cir. 2001). Method steps may

be performed simultaneously, as well as in other orders, unless actually specified otherwise. *See Moba*, 325 F.3d at 1313-14. Even if some steps of a claim are specified to be in a particular order, that does not require the remaining steps to be in a particular order. *E.g. Altiris, Inc. v. Sumantec Corp*., 318 F.3d 1363, 1369-71 (Fed. Cir. 2003). By incorrectly restricting the "measuring" requirement to an "uncompensated" result, Avidyne hopes to restrict the "compensation" requirement to occur after measurement. This would improperly restrict "compensating" from occurring simultaneously with measuring, or even before as the claim would now encompass.

The Specification. Nowhere in the '018 patent Abstract, Background, Summary, or Description of the Preferred Embodiment is mentioned the term "uncompensated attitude" or the functional limitation of "to obtain the uncompensated attitude of the mobile craft." In contrast, the specification broadly describes the "measuring" performed by the attitude determining device and does not limit the device to any particular structure. The Abstract of the '018 patent notes:

> . . . an attitude of the mobile craft with respect to the earth frame is *measured with the attitude determining device* . . . (DX 1, cover; emphasis added).

Similarly, the Background of the Invention states:

> Accordingly, the inventive method described herein below ensures a substantially accurate *measurement of aircraft attitude by the attitude determining device* with respect to the earth frame of reference. (DX 1, Col. 1:56-59; emphasis added).

The Summary of the Invention also broadly references this aspect as follows:

> An attitude of the mobile craft is *measured with the attitude determining device*… (DX 1, Col. 2: 5-6; Emphasis added.)

Thus, the claim term "measuring an attitude of said mobile craft with said attitude determining device" is broad enough to contemplate, for example, measuring an attitude of the mobile craft while at rest or moving, at start-up or in flight, using accelerometers, rate sensors,

gyros, or other sensors, in a device that may have one or more processors, and may or may not directly result in the production of an "uncompensated attitude." The Description of the Preferred Embodiment likewise makes clear that an attitude determining device may include acceleration sensors and/or rate sensors (e.g. DX 1, Col. 3:19 – 24), but does not disavow other structures that may be used for measuring.

Notably, the Description of the Preferred Embodiment describes an embodiment in which the inventive use of an attitude determining device is employed in two aspects: (1) with an at rest craft at start-up, and (2) with a moving craft. (DX 1, Col.4:7-36.) The method at least as described in connection with the moving craft embodiment is not consistent with Avidyne's improperly narrowed and sequentially constrained construction. Whether Avidyne can find some support for its proposed construction in some of the embodiments disclosed in the specification is insufficient to limit claims that are not so limited to that construction.

Regarding this embodiment, the Description discloses preferred operation both when the craft is at rest and when in motion. That disclosure initially discusses that embodiment's steps that would fulfill the "installing" and "sensing" steps of claims 1 and 16:

> In the present embodiment, upon ***installation*** of the device 20 on the instrumentation panel 30 of the craft 10, whose reference coordinate axes have been leveled to coincide with earth frame, ***the installation orientation thereof is automatically measured by the installed device*** 20 . . . (DX 1, Col. 4:7-10; emphasis added.)

In the case of the at rest craft, the disclosure discusses a sampling of the output of the acceleration sensors and determination by the processor in that embodiment that would fulfill the measuring requirement of claims 1 and 16:

> [A]fter the device is installed on the instrument panel . . . and power is subsequently activated to the device 20, an internal processor 52 of the device 20 samples the outputs of the acceleration senors [sic] . . . [and] static angles of the device 20 with respect to earth frame are determined by the processor . . . (DX 1, Col. 4:38-40.)

In this at rest case, the determination of the "static angles" determined by the attitude determining device could be argued to correspond to an "uncompensated attitude."

Subsequently, the Description notes a determination in that embodiment that would fulfill the "compensating" clause of claim 1:

> . . . the attitude of the craft 10 with respect to earth frame is determined by the processor 52 by subtracting the[]installation angles . . . from the static angles of the device 20 with respect to earth frame. (DX 1, Col. 4:47 – 50.)

Thus, the Description discloses an at rest embodiment in which a measurement is undertaken without first undertaking the compensation step.

This is but one embodiment disclosed by the specification, however, and does not provide a basis for improperly narrowing and sequentially constraining the claims. Significantly, the disclosure of the same embodiment just discussed also discloses a broader embodiment.

In the case of the moving craft, the Description continues on from the above noted passages to disclose a moving craft embodiment in which the compensation is performed before or simultaneously with the measurement, since the measurement readings of the rate sensors are computed conventionally:

> ***Thereafter,*** the pitch and roll attitude angles of the moving craft 10 ***are computed conventionally*** by the processor 52 ***via the rate sensors*** $\boldsymbol{\omega_x}$, $\boldsymbol{\omega_y}$ ω_z which are shown at block 56 of the device 20 and received by the processor 52. (DX 1, Col. 4:50-54; emphasis added.)

In essence, in this embodiment, when power is turned on the attitude determining device is compensated with the static orientation measurement, and when the craft moves thereafter the measurements made by the attitude determining device are already compensated.

The Prosecution History. Nothing in the prosecution, whether by way of amendment or argument, restricts "measuring an attitude of said mobile craft with said attitude determining device" to "using the **processor** of the attitude determining device **to process** the output of the

sensors of the attitude determining device **to obtain** the **uncompensated attitude** of the mobile craft." No unequivocal or clear disavowal of scope would limit the "measuring" clause. Thus, measuring may be performed while the craft is at rest or moving, at start-up or in flight, or by an attitude determining device that may have a variety of sensors and one or more processors, and may or may not directly result in the production of an "uncompensated attitude" value.

Moreover, during prosecution the inventors clearly established that the measuring and compensating steps are not sequence dependant. In fact, the inventors took the position that the measuring and compensating steps were undertaken as part of the same step. In responding to the only rejection, the inventors argued that the method was made up of only three steps, and that the measuring and compensating activities were one and the same:

> Independent claims 1 and 16 recite, in substance, a method of compensating for installation orientation of an attitude determining device on board a mobile craft *comprising the steps of* 1) installing the attitude determining device at an <u>unknown</u> orientation with respect to the reference coordinate system of the craft, 2) sensing the installation orientation while the craft is at rest to obtain a static orientation measurement of the device, and ***3) compensating the craft attitude measurement of the device with the static orientation measurement.*** (DX 4, Page 3; italics added.)

There is no basis to restrict the claims to a sequence in which a measurement is first undertaken to "obtain" an uncompensated attitude and then perform a subsequent compensating.

E. Compensating said craft attitude measurement of said device with said Device with Said Static Orientation Measurement to Obtain Attitude Information of Said Craft's Reference Coordinate System with Respect to Said Earth Frame Coordinate System (Claim 1):

The claim requirement of "compensating said craft attitude measurement of said device with said static orientation measurement to obtain attitude information of said craft's reference coordinate system with respect to said earth frame coordinate system" is interpreted as "using the static orientation measurement to neutralize the craft attitude measurement for the installation orientation of the attitude determining device to obtain the orientation of the craft relative to the earth."

Avidyne suggests that "compensating said craft attitude measurement of said device with

said static orientation measurement" is to be interpreted as "applying the said static orientation measurement determined in said sensing step to the uncompensated attitude of the craft determined in said measuring step to mathematically modify the uncompensated attitude of the craft determined in said measuring step to thereby adjust for a difference between that measured attitude of the craft and the craft's actual attitude relative to earth." Once again Avidyne is erroneously attempting to read specific embodiments selected by Avidyne into the claim, or that Avidyne itself generates, and improperly limit the claim by the specification. Avidyne further attempts to restrict the claimed method to a specific sequence of steps contrary to established law. Avidyne's proposal is wrong. The claimed compensating of the craft attitude measurement can occur simultaneously with the measurement and even before, as well as after.

The Claims. Claims 1 and 16 include final clauses that commence with "compensating" but there is a difference between the two clauses. Principally, since claim 16 includes additional steps of "storing" and "retrieving" while claim 1 does not, the compensating step of claim 16 references the "retrieved" static orientation measurement as well as a "processor" while claim 1 does not. The preamble of both claims 1 and 16 also commence with the clause "A method of compensating for installation orientation of an attitude determining device …" "Compensating" is to be interpreted consistently in the claims absent an intent to interpret the term differently. L3's interpretation of compensating is consistent.

As previously discussed in Section VI B, the ordinary meaning of the term "compensating" is to counterbalance, counteract or neutralize. *Merriam Webster's Collegiate Dictionary*, page 234 (10th Ed. 1995) (DX 6); *The American Heritage Dictionary*, page 385 (3rd Ed. 1992) (DX 7). It is error to deviate from this ordinary meaning which is consistent with the patent specification, since there is no clear directive in the specification to do so. *E.g. Bell*

Atlantic Network Servs., Inc. v. Covad Communications Group, Inc., 262 F.3d 1258, 1267 (Fed. Cir. 2001); *Constant v. Advanced Micro-Devices, Inc.*, 848 F.2d 1560, 1571 (Fed. Cir. 1988). This meaning is consistent with the meaning of "compensating for installation orientation of an attitude determining device" as is used in the preamble of claim 1.

The Specification. The Summary of the Invention nowhere uses the term "uncompensated." The Summary likewise does not refer to "applying" the static orientation measurement to the attitude determined in the measuring step. Rather, the Summary refers to the measurement *compensated with* the static orientation measurement. Neither the Abstract nor the Background mentions "applying" the static orientation measurement or "uncompensated."

The Summary of the Invention starts with a paragraph prefaced as "In accordance with the present invention," (DX 1, Col. 1:66). The Summary subsequently includes paragraphs stated to be specific to particular embodiments, i.e. "In one embodiment," (DX 1, Col. 2:10) and "In another embodiment," (DX 1, Col. 2:21). That initial paragraph of the Summary tracks broad claim 1 and specifies that a measured attitude is *compensated with* the static orientation measurement, but there is no limitation of the particular sequence to be followed and no prohibition of the compensation occurring simultaneously with the measurement. (DX 1, Col. 1:66-2:9.) Even the subsequent embodiments described in the Summary do not limit the compensation to a particular sequence. (DX 1, Col. 2:10-29.)

Avidyne's suggested construction further requires that a separate "uncompensated attitude" measurement must first be obtained each time a compensated attitude measurement is desired. The relevant portions of Avidyne's proposed definition are as follows:

> Applying the said static orientation measurement . . . to ***the*** uncompensated attitude of the craft . . . to mathematically modify ***the*** uncompensated attitude of the craft . . . to thereby adjust for a difference between ***that*** measured attitude of the craft and the craft's actual attitude relative to earth. (Emphasis added.)

The disclosed embodiment previously described in discussion of the "measuring" clause includes application of the inventive method to a moving craft in which an initial calculation is performed to determine the attitude of the craft with respect to the earth. In that embodiment, after the attitude determining device is initialized while at rest, "Thereafter, the …attitude angles of the moving craft 10 are computed conventionally by the processor via the rate sensors…" (DX 1, Col.4:50-52.) Significantly, while the craft is moving this is done without obtaining an uncompensated attitude, and without applying the static orientation measurement to each such uncompensated attitude obtained. In essence, the attitude determining device is compensated with the static orientation measurement, and when the craft moves thereafter the measurements made by the attitude determining device are already compensated.

In the Description of the Preferred Embodiment there is discussion of a number of alternative preferred approaches. Nowhere does the specification create a new definition of either "measuring" or "compensating" specific to this patent, or state that a specific sequence of compensating and measuring is required in order to "be" the invention. To the contrary, the Description closes with the express directive that the claims as broadly written were not to be limited to aspects of the preferred embodiment described in the specification:

> While the invention has been described herein in connection with a preferred embodiment, it should not be so limited, but rather construed in accordance with the breath and broad scope of the claim set appended hereto.
> (DX 1, Col. 5:54-57.)

<u>The Prosecution History</u>. The inventors never argued that their claimed invention differed from the prior art by a particular compensation technique or sequence of measuring and compensating. In responding to the only rejection issued during prosecution, the inventors did not reference a particular compensation method to the examiner. Rather, the inventors noted the breadth of the independent claims of the '018 patent as follows, and expressly argued that the

invention provides that the measuring and compensating may occur simultaneously:

> Independent claims 1 and 16 recite, in substance, a method of compensating for installation orientation of an attitude determining device on board a mobile craft *comprising the steps of* 1) installing the attitude determining device at an unknown orientation with respect to the reference coordinate system of the craft, 2) sensing the installation orientation while the craft is at rest to obtain a static orientation measurement of the device, and *3) compensating the craft attitude measurement of the device with the static orientation measurement.*
> (DX 4, page 3; emphasis added.)

The only argument presented to the examiner was the repeated clarification that the prior art "in no way shape or form addresses the problem of errors in installation orientation." (DX 4, page 2.) No argument relating to sequence was presented, other than to indicate the measuring and compensating may be considered the same step.

The examiner's Reasons for Allowance further reveal the inapplicability to the particular manner and sequence in which compensation is performed. The examiner allowed the application to issue stating, "[m]ajor emphasis is being placed upon the provision of an 'installing' an 'altitude [sic] determination device' at an 'unknown orientation' and 'compensating' the result with a 'static orientation measurement' in combination with other limitations of the said independent claim, and its dependent ones." (DX 5, page LC03394.) Nowhere does the examiner indicate that patentability was based on a particular sequence of compensating and measuring. There is no "clear disavowal of scope" that would be required to limit the claim as Avidyne proposes.

F. Storing Said Static Orientation Measurement in a Memory (Claim 16):

The claim requirement of "storing said static orientation measurement in a memory" is interpreted as "retaining static orientation measurement data within the attitude determining device."

Avidyne suggests that the interpretation should include the additional functional limitation of "persistently" retaining the static orientation measurement in a memory. Avidyne

also does not agree that the "memory" retains that information as "data", and suggests that the interpretation be "persistently retaining the static orientation measurement in a memory." Avidyne's interpretation does not agree with the disclosed embodiments, and adds a further limitation that nowhere appears in the '018 patent.

The Claims. Only claim 16 references "storing" or a "memory." Claim 16 subsequently references a "processor" of the attitude determining device and a step of "retrieving said static orientation measurement from said memory." As will be readily recognized, the terms storing, memory, retrieving and processor originate from the computer sciences. The ordinary meanings of "memory" and "storing" in the computer sciences are as follows:

> **memory** [comput sci] Any apparatus in which data may be stored and from which the same data may be retrieved; especially, the internal, high-speed, large-capacity working storage of a computer, as opposed to external devices. Also known as computer memory. *McMgraw-Hill Dictionary of Scientific and Technical Terms*, page 1237 (5th Ed. 1994). (DX 5.)
>
> **store** [comput sci] 1. To record data into a (static) data storage device. 2. To preserve data in a storage device. *McMgraw-Hill Dictionary of Scientific and Technical Terms*, page 1927 (5th Ed. 1994). (DX 5.)

The interpretation of L3 is consistent with the usage in the claims and the ordinary meaning of the terms in the technical field in which they originate. "Memory" is a generic term that is not restricted to any particular structure. The attitude determining device must provide a capacity to retain the information, without being limited to any particular structure or component of the device. As is established by the ordinary meaning of the claim terms, the static orientation measurement is retained in the form of "data," which is the medium in which a "memory" operates and the medium the act of "storing" operates upon.

The Specification. Neither the Abstract, Background, nor Summary mention a memory or the storing of information. The Description of the Preferred Embodiment, however, discusses

several different embodiments that incorporate different types of memory and storing. A "memory" is shown in Figures 5 and 6, but in block schematic form that does not show a particular structure or location in the attitude determining device. (DX 1; Col. 2:49-52.) Nowhere does the specification refer to "persistently" storing or retaining.

One type of memory discussed in the Description of the Preferred Embodiments is a "non-volatile memory" in which the installation orientation is initially stored:

> In the present embodiment, upon installation of the device 20 on the instrumentation panel 30 of the craft 10, whose reference coordinate axes have been leveled to coincide with earth frame, the installation orientation thereof is automatically measured by the installed device 20 and *stored* in a *non-volatile memory* thereof. (DX 1, Col. 4:7-12; emphasis added.)

In embodiments using a "non-volatile memory" for the stored information, when the attitude determining device 20 is installed and "subsequently power is activated to the device 20," the installation angles of the device are "read from non-volatile memory 54 of device 20." (DX 1, Col. 4:35-50.) The '018 patent describes how power to the attitude determining device may be turned off after the information is stored in a non-volatile memory, and that stored information will still be available to the attitude determining device from the memory when the power is turned back on. (DX 1, Col. 4:59-Col. 5:6.)

Another embodiment employing a different form of memory is also disclosed. If there is no non-volatile memory, once the power to the device is turned off the stored information is lost and must be re-inputted and stored in memory when power is restored:

> In attitude determining devices *in which there is no non-volatile memory*, the step of sensing the installation orientation of the device to obtain a static orientation measurement with respect to the reference coordinate system of the craft may be performed *each time the power is turned on* and the aircraft is in a static condition. The resulting static orientation measurement *may be stored in the memory* of the device for use in compensating for attitude measurements for the moving craft. (DX 1, Col. 5:45–53; emphasis added.)

The discussion of the different preferred embodiments is consistent with L3's interpretation of this claim requirement. Claims are to be interpreted to encompass the preferred embodiments. The storing in memory step must be interpreted broadly enough to encompass storing in a volatile memory that requires reintroducing and storing the information each time power to the device is turned off as well as in a non-volatile memory. Avidyne's allegation that storing in a memory requires information to be "persistently" retained is contrary to the disclosure of the specification and would exclude one of the preferred embodiments.

The Prosecution History. During prosecution the storing step was not argued and the inventors' discussion of claim 16 did not mention the storing step. Nothing in the prosecution history would restrict the storing step to "persistently" retaining the data, or departing from the ordinary meaning of the terms consistent with the specification.

G. Retrieving Said Static Orientation Measurement from Said Memory to a Processor of Said Device (Claim 16):

The claim requirement of "retrieving said static orientation measurement from said memory to a processor of said device" is interpreted as "providing static orientation measurement data to an electronic computational device within the attitude determining device."

Avidyne argues the clause is to be interpreted as "obtaining the previously stored static orientation measurement and feeding it to the processor of the attitude determining device." This step relates to the "storing" step of claim 16 previously discussed in that "retrieving", "memory" and "processor" originate from the computer science field and have ordinary meanings. The medium in which retrieving and processor operate is data. "Processor" is a broad term for computational devices, which left undefined would lead to potential for juror confusion.

The Claims. The claims do not specify a particular type or form of "processor." "Processor" is a term with an ordinary meaning that is in essence generic for a computing device:

> **processor** [comp sci] 1. A device that performs one or many functions, usually a central processing unit. Also known as an engine. 2. A program that transforms some input into some output, such as an assembler, compiler, or linkage editor. *McMgraw-Hill Dictionary of Scientific and Technical Terms*, page 1582 (5th Ed. 1994). (DX 2.)

"Retrieve" also has an ordinary meaning in the computer science field:

> **retrieve** [comp sci] To find and select specific information. *McMgraw-Hill Dictionary of Scientific and Technical Terms*, page 1701 (5th Ed. 1994). (DX 2.)

As previously discussed relative to the "storing" step of claim 16, a "memory" is "any apparatus in which data may be stored and from which the same data may be retrieved." The medium in which information is retrieved from a memory is data. L3's interpretation is consistent with the ordinary meaning of the claim terms.

The Specification. The Abstract, Summary of the Invention, and Brief Description of the Drawings do not use either the term "retrieving" or "processor." The Background of the Invention does refer to an attitude measurement compensated with the static orientation "in a processor of the device." (DX 1, Col. 1:59-62.) Figures 5 and 6 represent a processor 52 in schematic form, and the Description of the Preferred Embodiment discusses preferred embodiments that include a processor 52.

The Description of the Preferred Embodiment does not expressly use the term "retrieving" or "retrieve," but uses analogous terms such as being "read" from memory 54 (DX 1, Col. 4:45-46), "using" information from memory (Dx1, Col. 5:5-6), and information stored to be later "accessed" (DX 1, Col. 5:18-19). Nothing stated in the specification would require a deviation from the ordinary meaning of these claim terms. Although the specification does use the term "processor," simply stating this term does not assist the jury's understanding.

The Prosecution History. There was no argument during prosecution of the '018 patent that would restrict the ordinary meaning of the claim terms for interpretation of this clause.

H. Compensating Said Craft Attitude Measurement With Said Retrieved Static Orientation Measurement in Said Processor to Obtain Attitude Information of Said Craft's Reference Coordinate System with Respect to Said Earth Frame Coordinate System (Claim 16):

The claim requirement of "compensating said craft attitude measurement with said retrieved static orientation measurement in said processor to obtain attitude information of said craft's reference coordinate system with respect to said earth frame coordinate system" is interpreted as "using the static orientation measurement data in an electronic computational device to neutralize the craft attitude measurement for the installation orientation of the attitude determining device to obtain an orientation of the craft relative to the earth."

The "compensating" clause of claim 16 is similar to that of claim 1, with the addition in claim 16 of "with said retrieved" and "in said processor." Both parties' constructions of the "compensating" clause of claim 16 are, thus, substantially similar to the proposed constructions of the "compensating" clause of claim 1 previously discussed. L3, therefore, refers back to the prior discussions of "compensating," with the present discussion focusing on the additions. Avidyne's suggestion again imports limitations into the claim, and creates a sequence limitation that is not present anywhere in the '018 patent.

The Claims. As previously discussed, the preamble of claims 1 and 16 introduce the term "compensating," which is to be interpreted consistently in the claims absent an intent to interpret the term differently. L3's interpretation is consistent within claim 16, as well as the claims in general, and the ordinary meaning of the term. Method claims are not normally limited to a particular order of steps, and there is no basis to so limit claim 16 as Avidyne now proposes. *E.g. Moba, B.V. v. Diamond Automation, Inc.*, 325 F.3d 1306, 1313-14 (Fed. Cir. 2003); *Interactive Gift Express, Inc. v. Compuserve Inc.*, 256 F.3d 1323, 1342-43 (Fed. Cir. 2001).

The Specification. Again, the Summary of the Invention nowhere uses the term "uncompensated," or "applying" the static orientation measurement to the attitude determined in the measuring step. In contrast, the Summary of the Invention consistently refers to the

measurement *compensated with* the static orientation measurement.

As noted previously in Section VI E, Avidyne's construction of "compensating" imports a limitation that does not appear in the '018 patent. Specifically, Avidyne's construction requires that each time a compensated attitude measurement is desired, a separate "uncompensated attitude" measurement must first be obtained. Avidyne's construction of the "compensating" clause of claim 16 would require "applying" "the retrieved" measurement to a measured value each time to obtain compensated attitude information. This is not consistent with the disclosed embodiments. The relevant portions of Avidyne's suggested definition are as follows:

> applying ***the retrieved*** static orientation measurement . . . to ***the*** uncompensated attitude of the craft . . . to mathematically modify ***the*** uncompensated attitude of the craft . . . to thereby adjust for a difference between ***that*** measured attitude of the craft and the craft's actual attitude relative to earth. (Emphasis added.)

In the embodiment discussed in section VI E, the static orientation is stored in non volatile memory and power may be turned off. When the power is turned on the static orientation is retrieved from memory to the processor and the values read by the acceleration sensors while at rest are compensated to initialize the attitude determining device. This would fulfill the sensing, storing and retrieving steps in this embodiment. (DX 1, Col. 4:37-50.) When the craft moves thereafter, the measured attitudes are already compensated upon completion of the measurement: "Thereafter, the …attitude angles of the moving craft 10 are computed conventionally by the processor via the rate sensors…" (DX 1, Col.4:50-52.) This is done without obtaining an uncompensated attitude, and without applying a retrieved static orientation measurement to each such uncompensated attitude obtained. In essence, the attitude determining device is compensated with the static orientation measurement, and when the craft moves thereafter the measurements made by the attitude determining device are already compensated.

While claim 16 is broad enough to encompass an embodiment such as suggested by

Avidyne, the claim is not limited to such an embodiment.

The Prosecution History. Nothing in the prosecution history restricts the "compensating" clause to a sequence of measuring and compensating, or the static orientation measurement "applying to" rather than "compensation with." The claims were never distinguished from the prior art on either of these basis and the inventors actually treated the measuring and compensating as one step. (DX 4, Page 3.) There is no basis for limiting the broad scope of the claims as Avidyne consistently attempts.

Respectfully submitted,

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Dated: October 2, 2006

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DEFENDANT'S

EXHIBIT 1

US005841018A

United States Patent [19]

Watson et al.

[11] Patent Number: 5,841,018

[45] Date of Patent: Nov. 24, 1998

[54] **METHOD OF COMPENSATING FOR INSTALLATION ORIENTATION OF AN ATTITUDE DETERMINING DEVICE ONBOARD A CRAFT**

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[73] Assignee: **B. F. Goodrich Avionics Systems, Inc.**, Akron, Ohio

[21] Appl. No.: **785,553**

[22] Filed: **Dec. 13, 1996**

[51] **Int. Cl.**[6] **G01C 17/38**; G01C 21/00

[52] **U.S. Cl.** .... **73/1.81**; 73/178 R; 244/164

[58] **Field of Search** .... 73/1.79, 1.81, 73/1.78, 1.75, 1.76, 1.77, 178 R; 244/164, 171

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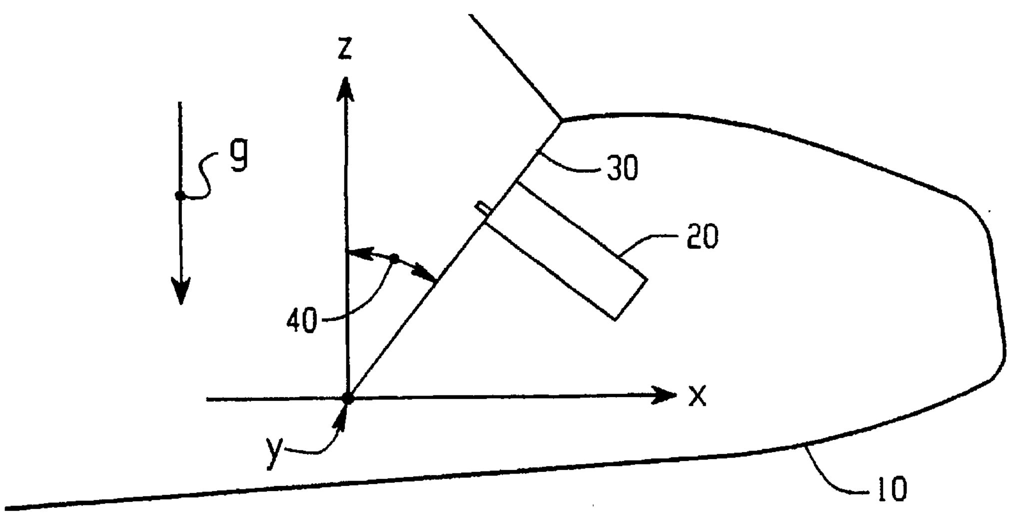
Primary Examiner—Max H. Noori
Attorney, Agent, or Firm—William E. Zitelli

[57] **ABSTRACT**

In accordance with the disclosed method, an attitude determining device which is installed onboard a mobile craft, like an aircraft, for example, at an unknown orientation with respect to the reference coordinate system of the craft senses its installation orientation with respect to an earth frame coordinate system when the craft is at rest to obtain a static orientation measurement thereof. Thereafter, an attitude of the mobile craft with respect to the earth frame is measured with the attitude determining device and such measurement is compensated with the static orientation measurement to obtain attitude information of the craft's reference coordinate system with respect to the earth frame coordinate system. The installation orientation of the attitude determining device may be sensed while the craft is at rest in either a leveled or unleveled condition.

20 Claims, 4 Drawing Sheets



DX 1

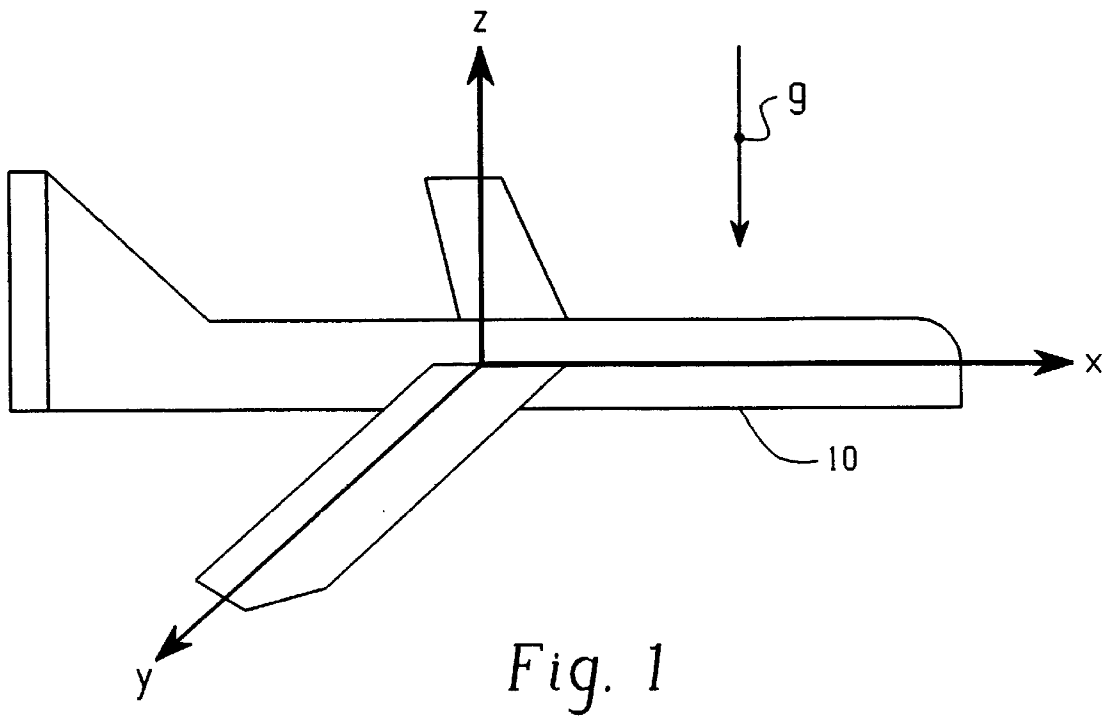


Fig. 1

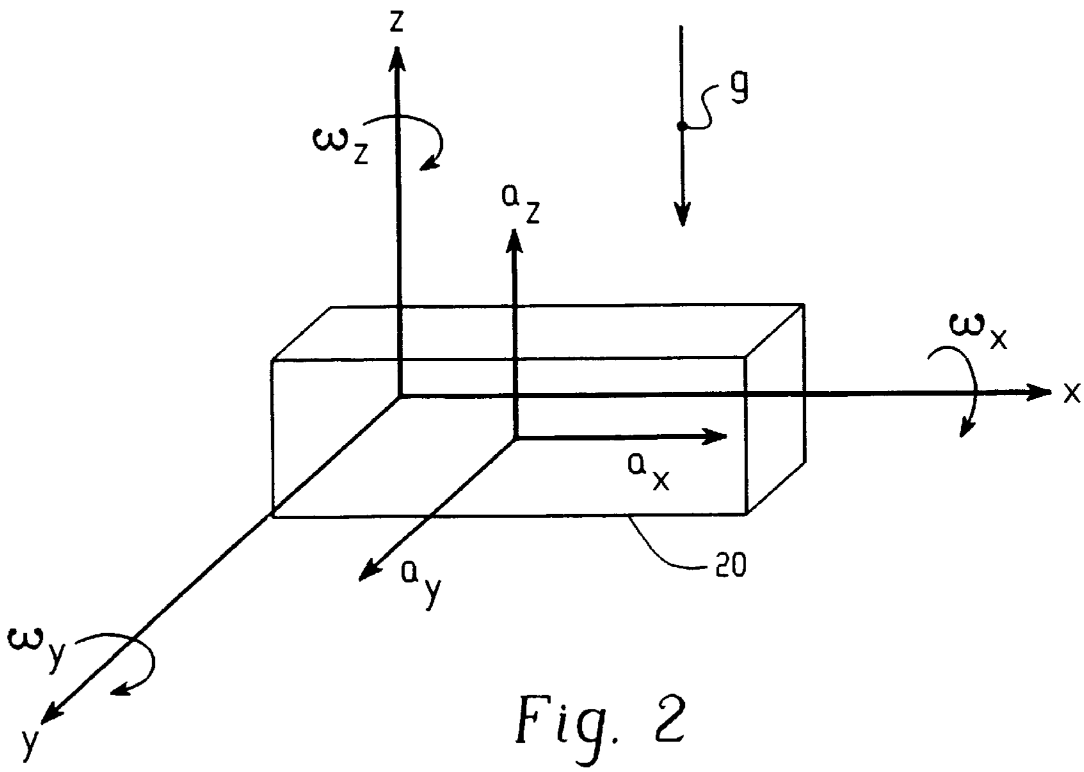


Fig. 2

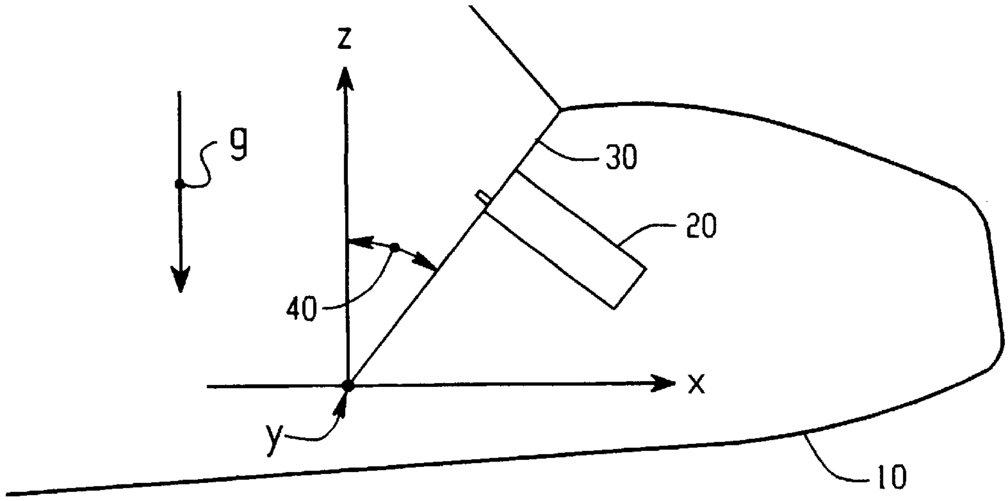


Fig. 3

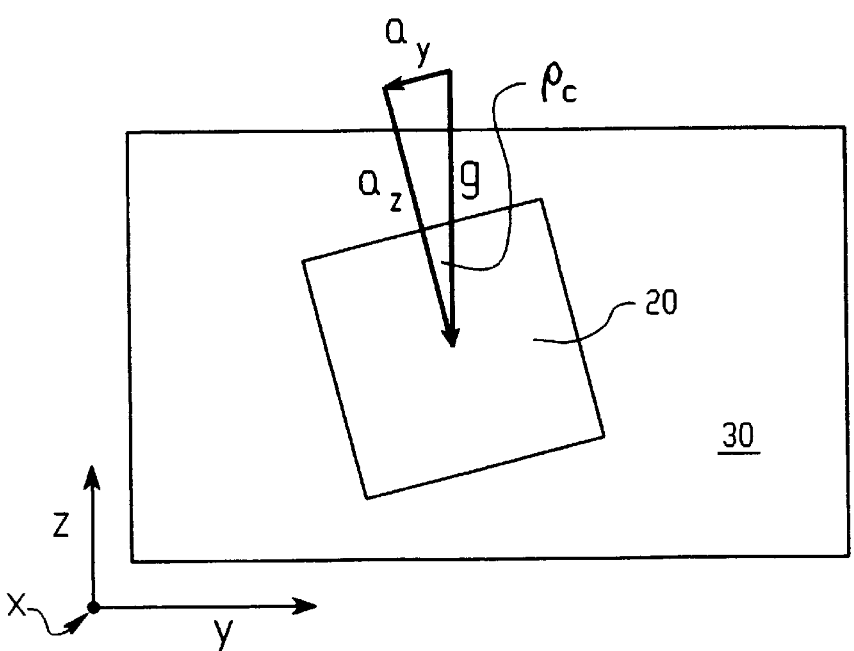
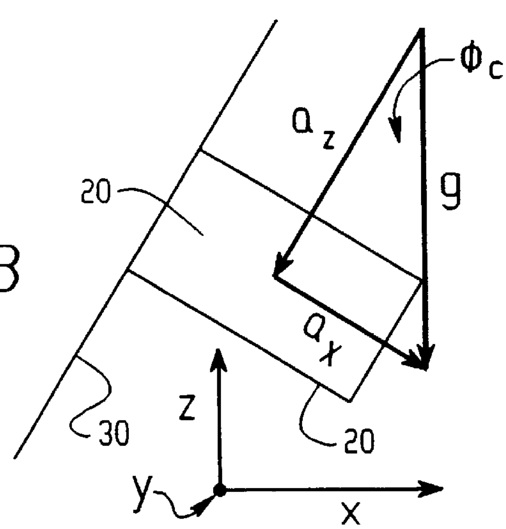
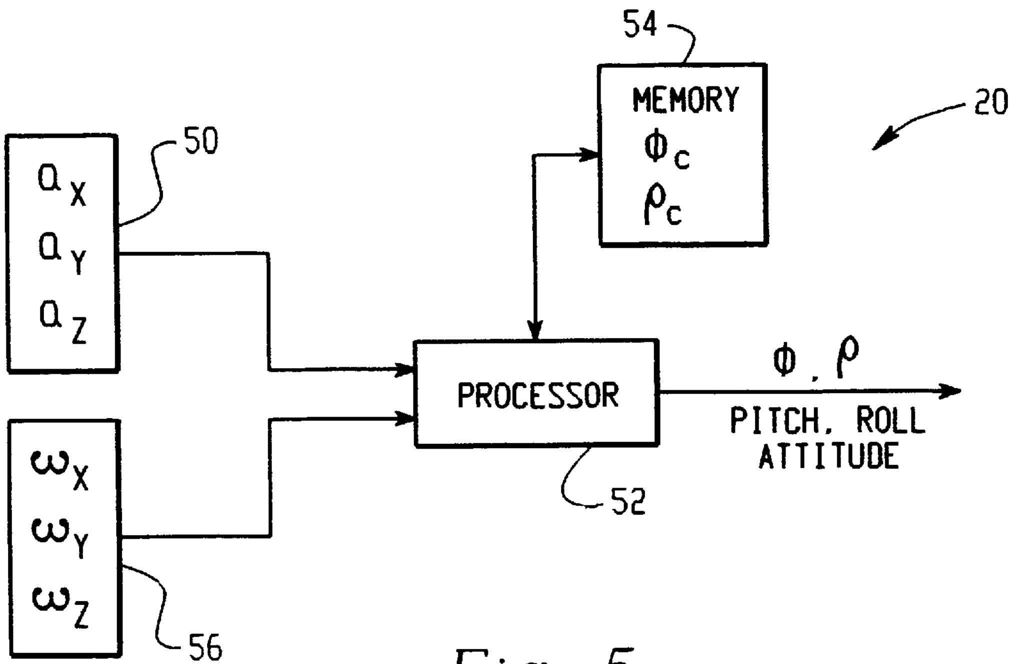


Fig. 4A

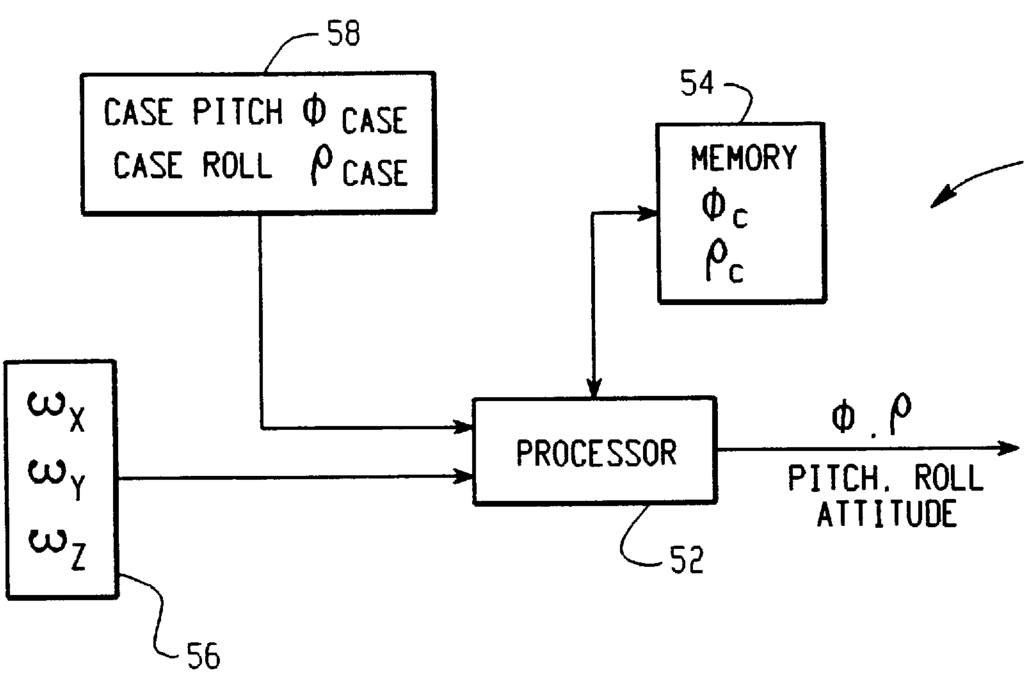
Fig. 4B





54
MEMORY
ϕ_c
ρ_c
20
50
a_X
a_Y
a_Z
PROCESSOR
ϕ , ρ
PITCH, ROLL
ATTITUDE
52
ω_X
ω_Y
ω_Z
56

Fig. 5



58
CASE PITCH ϕ CASE
CASE ROLL ρ CASE
54
MEMORY
ϕ_c
ρ_c
20
ω_X
ω_Y
ω_Z
PROCESSOR
ϕ , ρ
PITCH, ROLL
ATTITUDE
52
56

Fig. 6

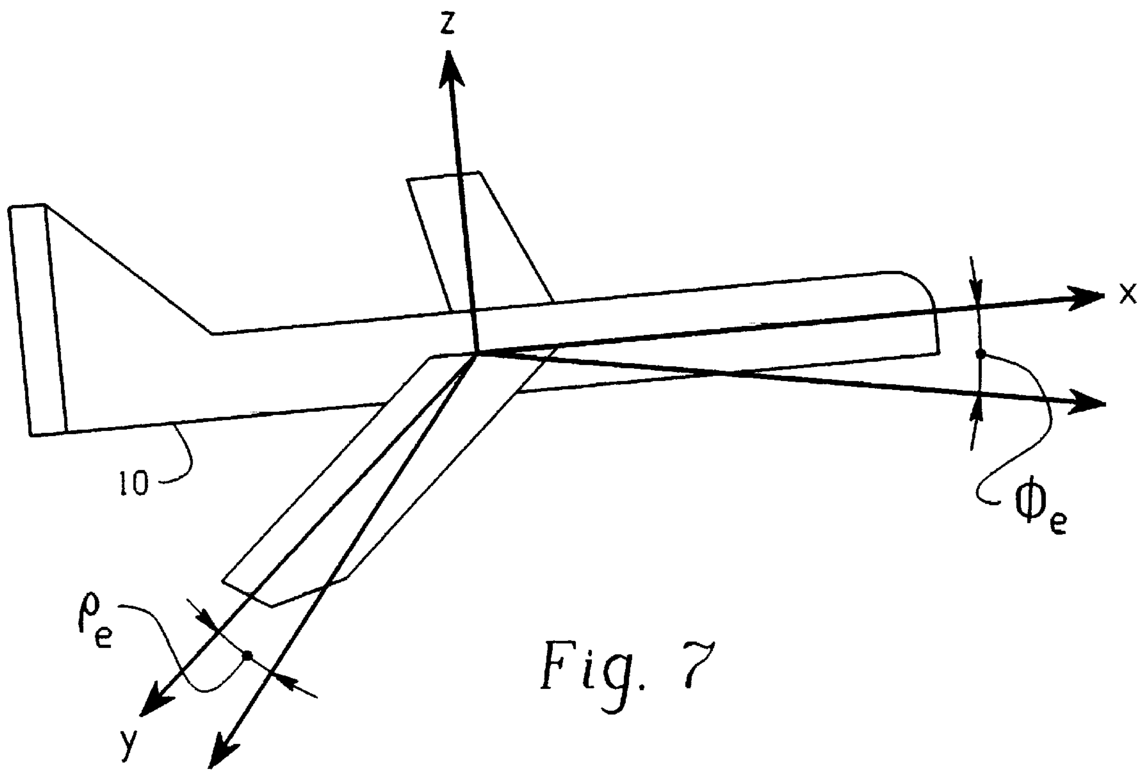


Fig. 7

METHOD OF COMPENSATING FOR INSTALLATION ORIENTATION OF AN ATTITUDE DETERMINING DEVICE ONBOARD A CRAFT

BACKGROUND OF THE INVENTION

The present invention relates to attitude determining devices onboard a mobile craft for determining the attitude of the craft's reference coordinate system with respect to an earth frame of reference, and more specifically, to a method of compensating an attitude measurement of such device for an unknown installation orientation with respect to the reference coordinate system of the craft.

Attitude determining devices for mobile craft, like aircraft, for example, measure the attitude of the moving craft with respect to an outside reference coordinate system, typically known as earth frame. The devices may be installed at a location in the craft in such a manner to be mechanically aligned with the reference coordinate system of the craft. The reference coordinate system of conventional aircraft comprises three orthogonal axes which include a longitudinal or X axis, a lateral or Y axis, and a vertical or Z axis. Motion of the aircraft is generally described as roll which is a rotation about the X axis, pitch which is a rotation about the Y axis and yaw which is a rotation about the Z axis. Pitch, roll and yaw positions are measured as the current angle between the aircraft reference coordinate system and earth frame. Conventionally, aircraft attitude determining devices primarily measure attitude of the aircraft in pitch and roll.

Any inaccuracy in installing an attitude determining device in the craft with respect to the reference coordinate system thereof will result in inaccurate measurement and presentation of the attitude of the craft to either the pilot or other system using the attitude information for display or control purposes. Currently, a method of installing these devices in an aircraft has been to accurately level the aircraft first, and then, install the device using shims or other mechanical apparatus to correctly position the device with respect to the three orthogonal axes forming the coordinate system of the aircraft. This procedure of leveling is adequate for devices mounted in locations of the aircraft remote from the cockpit, but when the device is to be mounted in a cockpit location, such as on an instrument panel, for example, shimming or other mechanical means of adjusting the installation orientation thereof may be precluded due to viewing angle restrictions, aesthetics, . . . etc. Accordingly, some other compensation method will be required.

Currently, units installed on an instrument panel in the cockpit of an aircraft have slots for roll axis alignment and internal mechanical means to accommodate pitch angles other than zero. However, these accommodations for pitch angles make the assumption of zero error in manufacturing tolerances of the aircraft panel angle.

Accordingly, the inventive method described herein below ensures a substantially accurate measurement of aircraft attitude by the attitude determining device with respect to the earth frame of reference. The static installation orientation is automatically determined by the device itself and the attitude measurement is compensated therewith in a processor of the device. Thus, the drawbacks of the current mechanical leveling and alignment procedures are avoided.

SUMMARY OF THE INVENTION

In accordance with the present invention, an attitude determining device which is installed onboard a mobile craft at an unknown orientation with respect to the reference coordinate system of the craft senses its installation orientation with respect to an earth frame coordinate system when the craft is at rest to obtain a static orientation measurement. An attitude of the mobile craft is measured with the attitude determining device and such measurement is compensated with the static orientation measurement to obtain attitude information of the craft's reference coordinate system with respect to the earth frame coordinate system.

In one embodiment, the acceleration of the attitude determining device is sensed for each of the axes of the reference coordinate system of the mobile craft while at rest and leveled, and a static attitude pitch and static attitude roll of the device are determined from trigonometric functions of ratios of the sensed accelerations. Accordingly, both of the measured attitude pitch and roll of the device are compensated with the static attitude pitch and the static attitude roll, respectively, in the attitude determining device to render attitude information of the craft's reference coordinate system with respect to the earth frame coordinate system.

In another embodiment, a static attitude of the mobile craft in pitch and roll is obtained while the craft is at rest and unleveled. Thereafter, the static attitude craft pitch is used in determining the static attitude pitch of the device and the static attitude craft roll is used in determining the static attitude roll of the device and such static attitude pitch and roll are used respectively to compensate for the measured attitude pitch and roll of the mobile craft in the attitude determining device.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an illustration of an aircraft, with it's reference coordinate system, onboard which an attitude determining device may be installed.

FIG. **2** is an illustration of an attitude determining device including conventional internal acceleration and rate sensors for three orthogonal axes X, Y and Z.

FIG. **3** is a sketch of an attitude determining device mounted on a panel in the cockpit of an aircraft at an unknown orientation to the reference coordinate system of the craft.

FIGS. **4**A and **4**B are illustrations exemplifying methods of determining the pitch and roll of the attitude determining device onboard a mobile craft using sensed acceleration measurements of the device in accordance with the present invention.

FIG. **5** is a block diagram schematic representing a suitable embodiment of an attitude determining device for performing the method in accordance with the present invention.

FIG. **6** is a block diagram schematic representing an alternate embodiment of an attitude determining device for performing another aspect of the present invention.

FIG. **7** is an illustration of an aircraft having its reference coordinate system unleveled with respect to an earth frame coordinate system allowing for offset angles of pitch and roll respectively from a level attitude.

DESCRIPTION OF THE PREFERRED EMBODIMENT

For the present embodiment, an aircraft will be used, by way of example, as a mobile craft, but it is understood that other similar craft may be used where ever an attitude of the craft is desired and measured with respect to an earth frame of reference coordinate system, hereinafter referred to sim-

ply as earth frame. An aircraft with its reference coordinate system is shown in FIG. **1** including a longitudinal axis depicted as an X axis, a lateral axis depicted as a Y axis, and a vertical axis depicted as a Z axis. Accordingly, roll of the aircraft may be measured as the angular rotation about the X axis, pitch of the aircraft may be measured by the angular rotation about the Y axis and yaw of the aircraft may be measured by the angular rotation about the vertical Z axis. All of these angles are measured with respect to the earth frame. Conventionally, an attitude determining device of an aircraft measures attitude in pitch and roll.

To accurately level the aircraft **10** such that its reference coordinate axes coincides with earth frame, the aircraft is adjusted in attitude such that an acceleration a_z sensed for the Z axis is set substantially equal to a gravity vector g, and the accelerations sensed in the X axis, a_x and in the Y axis, a_y, are set substantially to zero. When these conditions are sensed and stabilized, the aircraft **10** is considered leveled.

FIG. **2** is an illustration of an attitude determining device **20** which may include conventional internal acceleration sensors for the three orthogonal axes X, Y and Z, and may also include conventional rate sensors to measure the rotational motion ω_x, ω_y, and ω_z which are the rotational motions about the respective axes X, Y and Z. An example of such a device is an inertial reference unit manufactured by Honeywell, Inc., model no. HG2001AB02. The internal acceleration sensors (not shown) determine the gravity vector or local vertical g. Thereafter, rotational motion about the respective axes X, Y and Z is sensed by the rate sensors (also not shown), the output of which being integrated over time to maintain a real time craft attitude. Any accumulated integration errors may be removed during static periods by re-aligning the derived output of the device to the local vertical g which procedure is referred to as leveling or erection. These calculations are conventionally performed by a processor internal to the device which samples the sensor outputs and performs the initial and continuous algorithms to produce an attitude solution to be used for display in the aircraft or for a guidance and/or control application for the aircraft.

The attitude determining device **20** may be of a strap down system which is mechanically mounted to the case of the device or a gimballed instrument having elements which are free to rotate in inertial space independent of the case of the unit. In either case, in locating the attitude determining device **20** on board a moving craft, like an aircraft, for example, it may be installed at an unknown orientation with respect to the reference coordinate system of the craft which in the present embodiment are the three orthogonal axes X, Y and Z. It is desired that the device be mounted level with the lateral and longitudinal axes of the craft and aligned with the longitudinal X axis such as shown in FIG. **2**, but this may not always be possible due to errors in mechanical leveling or adjusting of the orientation and due to errors in manufacturing tolerances of the device and the aircraft structure where the device is being mounted. This is especially evident when the attitude determining device **20** is mounted on a panel in the cockpit of the aircraft **10** much as illustrated in the sketch of FIG. **3**.

Referring to FIG. **3**, when the attitude determining device **20** is installed on an aircraft instrument panel **30**, the device may not be aligned with the "waterline" or level line of the aircraft in order to compute accurate attitude information. This is because the panel is often not perpendicular to the waterline and it is not possible in most cases to exactly compensate mechanically for the panel angle offset **40** to the vertical or Z axis. In accordance with the present invention, a method is described below which ensures an accurate calculation of the attitude of a moving craft, like an aircraft, for example, by measuring the installation orientation of the device **20** with respect to the reference coordinate axes of the aircraft and compensating for this orientation mathematically in a processor of the device **20**.

In the present embodiment, upon installation of the device **20** on the instrumentation panel **30** of the craft **10**, whose reference coordinate axes have been leveled to coincide with earth frame, the installation orientation thereof is automatically measured by the installed device **20** and stored in a non-volatile memory thereof. For example, the pitch, ϕ_c and the roll, ρ_c are measured using the acceleration sensors of the device **20** and this measurement is exemplified by the illustrations of FIGS. **4**A and **4**B. In FIG. **4**A, the panel **30** and mounted device **20** is shown in the plane of the axes Z and Y to describe the measurement of the roll angle ρ_c of the installed device **20**. In the plane of the axes Z and Y, the acceleration vectors a_y and a_z are added vectorially to yield the gravity vector g. The installation roll angle ρ_c about the X axis is the angle between the vectors g and a_z and may be determined mathematically in accordance with a trigonometric function of the ratio of a_y to a_z.

Similarly, the perspective of the device **20** installed on the panel **30** in the plane of the axes X and Z is shown in FIG. **4**B. Referring to FIG. **4**B,in this perspective, the acceleration vectors a_z and a_x add up vectorially to yield the gravity vector g and the pitch angle ϕ_c is the angle between the vectors g and a_z which is a rotation about the Y axis. The installation pitch angle ϕ_c may be determined mathematically in accordance with a trigonometric function of the ratio of a_x to a_z. In the present embodiment, the trigonometric function used for determining the installed roll and pitch angles for static orientation of the device **20** is the arcsine.

A block diagram schematic representing a suitable embodiment of the attitude determining device is shown in FIG. **5**. Referring to FIG. **5**, after the device is installed on the instrument panel of a leveled craft **10**, for example, and power is subsequently activated to the device **20**, an internal processor **52** of the device **20** samples the outputs of the acceleration senors depicted in the block **50** in all three axes a_x,a_y,a_z. The static angles of the device **20** with respect to earth frame are determined by the processor **52** from the static acceleration measurements based on the trigonometric function described above. The installation angles ϕ_c and ρ_c are read from non-volatile memory **54** of the device **20** and the attitude of the craft **10** with respect to earth frame is determined by the processor **52** by subtracting these installation angles ϕ_c and ρ_c from the static angles of the device **20** with respect to earth frame. Thereafter, the pitch and roll attitude angles of the moving craft **10** are computed conventionally by the processor **52** via the rate sensors ω_x, ω_y ω_z which are shown at block **56** of the device **20** and received by the processor **52**. In a gimballed attitude determining device the angles of the spin axis, measured using synchros or other such devices, with respect to the case are corrected by subtracting the installation angles ϕ_c and ρ_c to yield actual aircraft pitch and roll attitude angles.

In summary, for the case in which the craft is leveled according to the description supplied above prior to sensing the installation orientation of device **20**, the processor **52** samples the outputs a_x,a_y and a_z of the acceleration sensors **50**. The static installation angles ϕ_c and ρ_c are determined by the processor **52** from the static acceleration measurements based on the trigonometric function described above and are stored in a non-volatile memory **54** for use in compensating the attitude measurements with respect to earth frame.

Power to device **20** may then be removed. Subsequent power application to device **20** would allow a measurement of the attitude of the aircraft, i.e. orientation of the aircraft's reference coordinate axes with respect to earth frame, to be correctly determined by processor **52** using ϕ_c and ρ_c from the memory **54**.

In some applications, the attitude determining device **20** may not include acceleration sensors **50** but rather include level sensors for sensing directly the pitch ϕ_{case} and roll ρ_{case} of the installed case with respect to the earth frame. A block diagram schematic suitable for exemplifying an alternate embodiment of the device **20** including level sensors is shown in FIG. **6** with the level sensing depicted at **58**. Like reference numerals are given to the other elements of the device **20** to match those described in connection with the embodiment of FIG. **5**. In operation, the processor receives the installation orientation angles ϕ_{case} and ρ_{case} measured by the level sensors at **58** and stores them in the non-volatile memory **54** as ϕ_c and ρ_c to be accessed subsequently in compensating for the attitude angle measurements as described in connection with the embodiment of FIG. **5**.

The foregoing method provides for compensating for the installation orientation of the device **20** for a leveled craft. If the craft **10** is not in a level attitude as shown in the exemplified illustration of FIG. **7**, the actual unlevel aircraft attitude may be measured i.e. reference coordinate axes of the aircraft with respect to earth frame, allowing the processor **52** to determine the offset angles of pitch and roll, ϕ_e and ρ_e, respectively, from a level attitude. These pitch and roll angle offsets from a level condition of the aircraft may be input either manually or electrically to the processor **52** of the device **20** as shown in FIGS. **5** and **6**. In addition, the static installation angles are measured by device **20** with respect to the unleveled aircraft coordinate axes. In order for the processor **52** of device **20** to calculate the effective static installation pitch and roll angles, ϕ_c and ρ_c of the case with respect to a level reference coordinate system of the craft **10**, it may subtract the measured offset angles from their respective measured installation angles. The effective static orientation measurements of the case with respect to the craft's reference coordinate system may then be stored in the memory **54** as shown in FIGS. **5** and **6** in order to compensate for the installation orientation of the device in the craft **10** as described supra.

In attitude determining devices in which there is no non-volatile memory, the step of sensing the installation orientation of the device to obtain a static orientation measurement with respect to the reference coordinate system of the craft may be performed each time the power is turned on and the aircraft is in a static condition. The resulting static orientation measurement may be stored in the memory of the device for use in compensating for attitude measurements for the moving craft.

While the invention has been described herein in connection with a preferred embodiment, it should not be so limited, but rather construed in accordance with the breath and broad scope of the claim set appended hereto.

We claim:

1. A method of compensating for installation orientation of an attitude determining device on-board a mobile craft with respect to a reference coordinate system of said craft to obtain attitude information of said craft from said device based on an earth frame coordinate system, said method comprising the steps of:

installing said attitude determining device on-board said mobile craft at an unknown orientation with respect to said reference coordinate system of said craft;

sensing the installation orientation of said attitude determining device with respect to said earth frame coordinate system when said craft is at rest to obtain a static orientation measurement of said device;

measuring an attitude of said mobile craft with said attitude determining device; and

compensating said craft attitude measurement of said device with said static orientation measurement to obtain attitude information of said craft's reference coordinate system with respect to said earth frame coordinate system.

2. The method in accordance with claim **1** wherein the reference coordinate system of said craft includes three orthogonal axes—a vertical or z axis, a longitudinal or x axis and a lateral or y axis.

3. The method in accordance with claim **2** wherein the step of sensing includes:

leveling the craft while at rest such that the z axis is aligned with a gravity vector and no substantial at rest acceleration exists at the x and y axes;

sensing the acceleration at the device for each of said three axes—a(x), a(y) and a(z) while the craft is at rest and leveled; and

determining the static orientation measurement of said device based on a function of said three sensed axis accelerations—a(x), a(y) and a(z).

4. The method in accordance with claim **3** wherein the step of determining includes:

determining a static attitude pitch of the device as a trigonometric function of a ratio of the sensed accelerations a(x) and a(z); and

determining a static attitude roll of the device as a trigonometric function of a ratio of the sensed accelerations a(y) and a(z); and

wherein the static orientation measurement of the device comprises the determined static attitude pitch and static attitude roll.

5. The method in accordance with claim **4** wherein the step of measuring includes measuring an attitude pitch and an attitude roll of the mobile craft with said device; and the step of compensating includes compensating the measured attitude pitch with the static attitude pitch and compensating the measured attitude roll with the static attitude roll.

6. The method in accordance with claim **2** wherein the step of sensing includes:

sensing the acceleration at the device for each of said three axes—a(x), a(y) and a(z) while the craft is at rest and unleveled;

obtaining a static attitude of the craft while at rest and unleveled;

determining the static orientation measurement of said device based on said static craft attitude and a function of said three sensed axis accelerations—a(x), a(y) and a(z).

7. The method in accordance with claim **6** wherein the step of obtaining includes:

obtaining a static craft pitch and a static craft roll; and the step of determining includes:

determining a static attitude pitch of the device as a trigonometric function of a ratio of the sensed accelerations a(x) and a(z) and said static craft pitch; and

determining a static attitude roll of the device as a trigonometric function of a ratio of the sensed accelerations a(y) and a(z) and said static craft roll; and

wherein the static orientation measurement of the device comprises the determined static attitude pitch and static attitude roll.

8. The method in accordance with claim **7** wherein the step of measuring includes measuring an attitude pitch and an attitude roll of the mobile craft with said device; and the step of compensating includes compensating the measured attitude pitch with the static attitude pitch and compensating the measured attitude roll with the static attitude roll.

9. The method in accordance with claim **1** wherein the step of sensing includes:

leveling the craft while at rest;

sensing an installation pitch and an installation roll of the device while the craft is at rest and leveled; and

wherein the static orientation measurement of the device comprises the sensed installation pitch and roll of the device.

10. The method in accordance with claim **9** wherein the step of measuring includes measuring an attitude pitch and an attitude roll of the mobile craft with said device; and the step of compensating includes compensating the measured attitude pitch with the sensed installation pitch and compensating the measured attitude roll with the sensed installation roll.

11. The method in accordance with claim **1** wherein the step of sensing includes:

sensing an installation pitch and an installation roll of the device while the craft is at rest and unleveled;

obtaining a static attitude pitch and a static attitude roll of the craft while at rest and unleveled;

determining a static attitude pitch of said device based on a combination of said static craft attitude pitch and said installation pitch and a static attitude roll of the device based on a combination of said static craft attitude roll and said installation roll;

wherein the static orientation measurement of the device comprises the determined static device attitude pitch and static device attitude roll.

12. The method in accordance with claim **11** wherein the step of measuring includes measuring an attitude pitch and an attitude roll of the mobile craft with said device; and the step of compensating includes compensating the measured attitude pitch with the static device attitude pitch and compensating the measured attitude roll with the static device attitude roll.

13. The method in accordance with claim **1** wherein the mobile craft is an aircraft, and the attitude device is installed on an instrumentation panel of said aircraft.

14. The method in accordance with claim **1** wherein the attitude determining device comprises a strapdown attitude instrument.

15. The method in accordance with claim **1** wherein the attitude determining device comprises a gimballed attitude instrument.

16. A method of compensating for installation orientation of an attitude determining device on-board a mobile craft with respect to a reference coordinate system of said craft to obtain attitude information of said craft from said device based on an earth frame coordinate system, said method comprising the steps of:

installing said attitude determining device on-board said mobile craft at an unknown orientation with respect to said reference coordinate system of said craft;

sensing the installation orientation of said attitude determining device with respect to said earth frame coordinate system when said craft is at rest to obtain a static orientation measurement of said device;

storing said static orientation measurement in a memory;

measuring an attitude of said mobile craft with said attitude determining device;

retrieving said static orientation measurement from said memory to a processor of said device; and

compensating said craft attitude measurement with said retrieved static orientation measurement in said processor to obtain attitude information of said craft's reference coordinate system with respect to said earth frame coordinate system.

17. The method in accordance with claim **16** wherein the step of sensing includes:

sensing the installation orientation of the device with sensors disposed at the device;

receiving in the processor sensed orientation data of said sensors; and

processing the received data in the processor to obtain the static orientation measurement of the device.

18. The method in accordance with claim **17** wherein the step of sensing includes sensing the installation orientation of the device with acceleration sensors.

19. The method in accordance with claim **17** wherein the step of sensing includes sensing the installation orientation of the device with level sensors.

20. The method in accordance with claim **16** wherein the step of compensating includes:

obtaining a static attitude of the craft while at rest and unleveled;

providing said static craft attitude to the processor of said device; and

compensating said craft attitude measurement with said retrieved static orientation measurement and static craft attitude in said processor to obtain attitude information of the craft's reference coordinate system with respect to the earth frame coordinate system.

* * * * *

DEFENDANT'S

EXHIBIT 2

McGraw-Hill Dictionary of Scientific and Technical Terms

Fifth Edition

Sybil P. Parker
Editor in Chief

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DX 2

On the cover: Photomicrograph of crystals of vitamin B_1.
(*Dennis Kunkel, University of Hawaii*)

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molar volumes of the liquid and vapor. { ¦gibz 'pȯint·iŋ i,kwā·zhən }

Gibbs rule *See* Gibbs phase rule. { 'gibz ,rül }

Gibbs system [STAT MECH] **1.** A hypothetical replica of a physical system. **2.** A set of such replicas forming an ensemble. { 'gibz ,sis·təm }

gibleh *See* ghibli. { 'gib·lə }

gibli *See* ghibli. { 'gib·lē }

giboulee *See* galerne. { jə'bü·lē }

Gibraltar stone *See* onyx marble. { jə'brȯld·ər ,stōn }

Gibrat's distribution [MATH] The distribution of a variable whose logarithm has a normal distribution. { zhē'bräz di·strə'byü·shən }

gid [VET MED] A chronic brain disease of sheep, less frequently of cattle, characterized by forced movements of circling or rolling, caused by the larval form of the tapeworm *Multiceps multiceps*. { gid }

Giegy-Hardisty process [CHEM ENG] The production of sebacic acid from castor oil or its acids by reaction of the acid at a high temperature with caustic alkali. { 'gē·gē 'här·də·stē ,präs·əs }

Giemsa stain [CHEM] A stain for hemopoietic tissue and hemoprotozoa consisting of a stock glycerol methanol solution of eosinates of Azure B and methylene blue with some excess of the basic dyes. { 'gēm·sə ,stān }

Giesler coal test [ENG] A plastometric method for estimating the coking properties of coals. { 'gēs·lər 'kōl ,test }

gifblaar poison *See* fluoroacetic acid. { 'gif,blär ,pȯiz·ən }

giga- [SCI TECH] A prefix representing 10^9, which is 1,000,000,000, or a billion. Abbreviated G. Also known as kilomega- (deprecated usage). { 'gig·ə }

gigabit [COMMUN] One billion bits, or 1,000,000,000 bits. Also known as billibit (deprecated usage). { 'gig·ə,bit }

gigacycle *See* gigahertz. { 'gig·ə,sī·kəl }

gigaelectronvolt [PHYS] A unit of energy, used primarily in high-energy physics, equal to 10^9 electronvolts or $(1.60210 \pm 0.00007) \times 10^{-10}$ joule. Abbreviated GeV. { ¦gig·ə·i'lek,trän,vōlt }

gigaflops [COMPUT SCI] A unit of computer speed, equal to 10^9 flops. { 'gig·ə,fläps }

gigahertz [COMMUN] Unit of frequency equal to 10^9 hertz. Abbreviated GHz. Also known as gigacycle (gc); kilomegacycle; kilomegahertz. { 'gig·ə,hərts }

gigantism [MED] Abnormal largeness of the body due to hypersecretion of growth hormone. { jī'gan,tiz·əm }

Giganturoidei [VERT ZOO] A suborder of small, mesopelagic actinopterygian fishes in the order Cetomimiformes having large mouths and strong teeth. { jī,gan·tə'rȯid·ē,ī }

gigawatt [ELEC] One billion watts, or 10^9 watts. Abbreviated GW. { 'gig·ə,wät }

gigging [TEXT] Passing a fabric across rollers equipped with teasels to produce a nap on the surface. { 'gig·iŋ }

gig mill [TEXT] A textile mill employing rotary wire cylinders for napping. { 'gig ,mil }

GIGO *See* garbage in, garbage out. { 'gī,gō }

gigohm [ELEC] One thousand megohms, or 10^9 ohms. { 'gig,ōm }

Gila monster [VERT ZOO] The common name for two species of reptiles in the genus *Heloderma* (Helodermatidae) distinguished by a rounded body that is covered with multicolored beaded tubercles, and a bifid protrusible tongue. { 'hē·lə ,män·stər }

gilbert [ELECTROMAG] The unit of magnetomotive force in the electromagnetic system, equal to the magnetomotive force of a closed loop of one turn in which there is a current of $1/(4\pi)$ abamp. { 'gil·bərt }

Gilbert circuit [ELECTR] A circuit that compensates for nonlinearities and instabilities in a monolithic variable-transconductance circuit by using the logarithmic properties of diodes and transistors. { 'gil·bərt ,sər·kət }

Gilbrethian variables [IND ENG] A system of three sets of variables that are considered to be intrinsic to every task: variables involving the response of the worker to anatomic and psychological factors, environmental variables, and variables of motion; used in analyzing and designing work systems. { gil'breth·ē·ən 'ver·ē·ə·bəlz }

Gilbreth's micromotion study [IND ENG] A time and motion study based on the concept that all work is performed by using a relatively few basic operations in varying combinations and sequence; basic elements (therbligs) include grasp, search, move, reach, and hold. { 'gil·brəths ¦mī·krō¦mō·shən ,stəd·ē }

gilding [GRAPHICS] Overlaying material with a thin layer of gold. { 'gild·iŋ }

gilding metal [MET] A copper alloy (about 90% copper, 10% zinc) used to jacket small-arms bullets, to form detonator or primer cups, and to form rotating bands for artillery projectiles; it can be readily engraved by the lands as the projectile moves down the bore. { 'gild·iŋ ,med·əl }

gill [MECH] **1.** A unit of volume used in the United States for the measurement of liquid substances, equal to ¼ U.S. liquid pint, or to $1.1829411825 \times 10^{-4}$ cubic meter. **2.** A unit of volume used in the United Kingdom for the measurement of liquid substances, and occasionally of solid substances, equal to ¼ U.K. pint, or to approximately 1.42065×10^{-4} cubic meter. [MYCOL] A structure consisting of radially arranged rows of tissue that hang from the underside of the mushroom cap of certain basidiomycetes. [VERT ZOO] The respiratory organ of water-breathing animals. Also known as branchia. { gil }

gill cover [VERT ZOO] The fold of skin providing external protection for the gill apparatus of most fishes; it may be stiffened by bony plates and covered with scales. { 'gil kəv·ər }

Gilles de la Tourette syndrome *See* Tourette's syndrome. { ,zhēl də lä tü'ret ,sin,drōm }

Gillespie equilibrium still [ANALY CHEM] A recirculating equilibrium distillation apparatus used to establish azeotropic properties of liquid mixtures. { gə'les·pē ,ē·kwə'libre·əm ¦stil }

gillespite [MINERAL] $BaFeSi_4O_{10}$ A micalike mineral composed of barium and iron silicate. { gə'le,spīt }

Gilliland correlation [CHEM ENG] Approximation method for distillation-column calculations; correlates reflux ratio and number of plates for the column as functions of minimum reflux and minimum plates. { gə'lil·ənd ,kä·rə,lā·shən }

gill net [ENG] A net that entangles the gill covers of fish. { 'gil ,net }

gill raker [VERT ZOO] One of the bony processes on the inside of the branchial arches of fishes which prevents the passage of solid substances through the branchial clefts. { 'gil ,rāk·ər }

Gilmour heat-exchange method [ENG] Thermal design method for heat exchangers by solution of five unique equations containing a minimum number of variables and involving tube-side, shell-side, tube-wall, and dirt resistance. { 'gil·mȯr 'hēt iks,chānj ,meth·əd }

gilsonite [MINERAL] A variety of asphalt; it has black color, brilliant luster, brown streaks, and conchoidal fracture. { 'gil·sə,nīt }

gimbal [ENG] **1.** A device with two mutually perpendicular and intersecting axes of rotation, thus giving free angular movement in two directions, on which an engine or other object may be mounted. **2.** In a gyro, a support which provides the spin axis with a degree of freedom. **3.** To move a reaction engine about on a gimbal so as to obtain pitching and yawing correction moments. **4.** To mount something on a gimbal. { 'gim·bəl }

gimbaled inertial system [NAV] An inertial guidance system that makes use of a three-gimbal mounting whose inner gimbal is a stable platform on which three gyroscopes and accelerometers are mounted; the gyroscopes sense any rotation of the vehicle and drive the gimbals in the opposite direction, so that the inner platform remains fixed in inertial space. { 'gim·bəld i'nər·shəl ,sis·təm }

gimbaled motor [AERO ENG] A rocket engine mounted on a gimbal. { 'gim·bəld 'mōd·ər }

gimbaled nozzle [MECH ENG] A nozzle supported on a gimbal. { 'gim·bəld 'näz·əl }

gimbal freedom [ENG] Of a gyro, the maximum angular displacement about the output axis of a gimbal. { 'gim·bəl ,frē·dəm }

gimbaling error [NAV] That error introduced in a gyro compass by the tilting of its gimbal mounting system due to horizontal acceleration caused by motion of the vessel, such as rolling. { 'gim·bə·liŋ ,er·ər }

gimballess inertial navigation equipment *See* strapped-down inertial navigation equipment. { 'gim·bə·ləs i¦nər·shəl ,nav·ə'gā·shən i,kwip·mənt }

gimbal lock [ENG] A condition of a two-degree-of-freedom gyro wherein the alignment of the spin axis with an axis of freedom deprives the gyro of a degree-of-freedom and therefore its useful properties. { 'gim·bəl ,läk }

gimlet [DES ENG] A small tool consisting of a threaded tip,

GILA MONSTER

Gila monster *(Heloderma suspectum)*, about 20 inches (50 centimeters) long.

or nuclear system. **2.** Occasionally, the reciprocal of the quantity in the first definition. { ¦jī·rō·mag'ned·ik 'rā·shō }

gyromagnetics [ELECTROMAG] The study of the relation between the angular momentum and the magnetization of a substance as exhibited in the gyromagnetic effect. { ¦jī·rō·mag'ned·iks }

gyropendulum [MECH ENG] A gravity pendulum attached to a rapidly spinning gyro wheel. { ¦jī·rō¦pen·jə·ləm }

Gyropidae [INV ZOO] A family of biting lice in the order Mallophaga; members are ectoparasites of South American rodents. { jə'räp·ə,dē }

gyroplane [AERO ENG] A rotorcraft whose rotors are not power-driven. { 'jī·rō,plān }

gyrorepeater [ENG] That part of a remote indicating gyro compass system which repeats at a distance the indications of the master gyro compass system. { ¦jī·rō·ri'pēd·ər }

gyroscope [ENG] An instrument that maintains an angular reference direction by virtue of a rapidly spinning, heavy mass; all applications of the gyroscope depend on a special form of Newton's second law, which states that a massive, rapidly spinning body rigidly resists being disturbed and tends to react to a disturbing torque by precessing (rotating slowly) in a direction at right angles to the direction of torque. Also known as gyro. { 'jī·rə,skōp }

GYROSCOPE

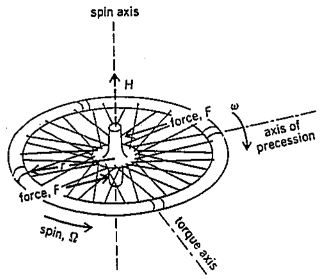


Illustration of gyroscope principle. Bicycle wheel with high spin velocity Ω has angular momentum $H = mr^2\,\Omega$, where m and r are mass and radius of wheel. Torque T resulting from force F produces precession with small angular velocity $\omega = T/H$ about axis perpendicular to both spin axis and torque axis.

gyroscopic-clinograph method [ENG] A method used in borehole surveying which measures time, temperature, and temperature on 16-millimeter film while a gyroscope maintains the casing on a fixed bearing. { ,jī·rə'skäp·ik 'klīn·ə,graf ,meth·əd }

gyroscopic compass *See* gyrocompass. { ,jī·rə'skäp·ik 'kām·pəs }

gyroscopic/Coriolis-type mass flowmeter [ENG] An instrument consisting of a C-shaped pipe and a T-shaped leaf-spring tuning fork which is excited by an electromagnetic forcer, resulting in an angular deflection of the pipe which is directly proportional to the mass-flow rate within the pipe. { ,jī·rə'skäp·ik ,kȯr·ē'ō·ləs ,tīp ¦mas 'flō,mēd·ər }

gyroscopic couple [MECH ENG] The turning moment which opposes any change of the inclination of the axis of rotation of a gyroscope. { ,jī·rə'skäp·ik 'kəp·əl }

gyroscopic drift [NAV] The horizontal rotation of the spin axis of a gyroscope about the drift axis. { ,jī·rə'skäp·ik 'drift }

gyroscopic horizon [NAV] A gyroscopic instrument that indicates the lateral and longitudinal attitude of an aircraft by simulating the natural horizon. { ,jī·rə'skäp·ik hə'rīz·ən }

gyroscopic mass flowmeter [ENG] An instrument in which the torque on a rotating pipe of suitable shape, through which a fluid is made to flow, is measured to determine the mass flow through the pipe. { ,jī·rə'skäp·ik ¦mas 'flō,mēd·ər }

gyroscopic precession [MECH] The turning of the axis of spin of a gyroscope as a result of an external torque acting on the gyroscope; the axis always turns toward the direction of the torque. { ,jī·rə'skäp·ik prē'sesh·ən }

gyroscopics [MECH] The branch of mechanics concerned with gyroscopes and their use in stabilization and control of ships, aircraft, projectiles, and other objects. { ,jī·rə'skäp·iks }

gyrosextant [NAV] A sextant provided with a gyroscope for the purpose of determining the horizontal. { ¦jī·rō'sek·stənt }

gyrostabilizer [ENG] A gyroscope used to stabilize ships and airplanes. { ¦jī·rō'stā·bə,līz·ər }

gyrotron [ELECTR] **1.** A device that detects motion of a system by measuring the phase distortion that occurs when a vibrating tuning fork is moved. **2.** A type of microwave tube in which microwave amplification or generation results from cyclotron-resonance coupling between microwave fields and an electron beam in vacuum. Also known as cyclotron-resonance maser. { 'jī·rə,trän }

gyro wheel [MECH ENG] The rapidly spinning wheel in a gyroscope, which resists being disturbed. { 'jī·rō ,wēl }

gyrus [ANAT] One of the convolutions (ridges) on the surface of the cerebrum. { 'jī·rəs }

gyttja [GEOL] A fresh-water anaerobic mud containing an abundance of organic matter; capable of supporting aerobic life. { 'yi,chä }

of a pure substance changes to a liquid. Abbreviated mp. **2.** For a solution of two or more components, the temperature at which the first trace of liquid appears as the solution is heated. { 'melt·iŋ ,pȯint }

melting profile [BIOCHEM] A plot of the degree of denaturation of the strands in a nucleic acid duplex in a specified time as a function of temperature. { 'melt·iŋ ,prō,fīl }

melting rate [MET] In electric arc welding, the weight or length of electrode melted in a specified unit of time. Also known as burn-off rate; melt-off rate. { 'melt·iŋ ,rāt }

melting ratio [MET] The ratio of metal weight to fuel weight in a melting process. { 'melt·iŋ ,rā·shō }

melting temperature [BIOCHEM] The temperature at which denaturing occurs for half of the double helices of deoxyribonucleic acid. { 'melt·iŋ ,tem·prə·chər }

melt instability [MECH] Instability of the plastic melt flow through a die. { 'melt ,in·stə'bil·əd·ē }

melt loading [ORD] Process of melting solid explosive by heat and pouring into bombs, projectiles, and the like to solidify. Also known as cast loading. { 'melt ,lōd·iŋ }

melt-off rate *See* melting rate. { 'melt,ȯf ,rāt }

melton [TEXT] A fabric with all-wool or cotton warp and woolen weft; the face is napped carefully to raise the nap straight up, showing the weave clearly. Also known as beaver cloth; kersey. { 'mel·tən }

melt spinning [TEXT] A process by which nylon, polyester, or glass is melted to allow it to be extruded into fibers through a spinneret. { 'melt,spin·iŋ }

melt strength [MECH] Strength of a molten plastic. { 'melt ,streŋkth }

melt-through [NUCLEO] An accident in a nuclear reactor in which melting of the fuel core (meltdown) leads to runaway melting of nuclear fuel out of the bottom of the reactor, down through the concrete mat below, and into the earth. Also known as China syndrome. { 'melt ,thrü }

meltwater [HYD] Water derived from melting ice or snow, especially glacier ice. { 'melt,wȯd·ər }

Melusinidae [INV ZOO] A family of orthorrhaphous dipteran insects in the series Nematocera. { ,mel·ə'sin·ə,dē }

Melyridae [INV ZOO] The soft-winged flower beetles, a large family of cosmopolitan coleopteran insects in the superfamily Cleroidea. { mə'lir·ə,dē }

member [CIV ENG] A structural unit such as a wall, column, beam, or tie, or a combination of any of these. [GEOL] A rock stratigraphic unit of subordinate rank comprising a specially developed part of a varied formation. [MATH] **1.** An element of a set. **2.** For an equation, the expression on either side of the equality sign. { 'mem·bər }

membership function [MATH] The characteristic function of a fuzzy set, which assigns to each element in a universal set a value between 0 and 1. { 'mem·bər,ship ,fəŋk·shən }

Membracidae [INV ZOO] The treehoppers, a family of homopteran insects included in the series Auchenorrhyncha having a pronotum that extends backward over the abdomen, and a vertical upper portion of the head. { mem'bras·əd·ē }

membrane [BUILD] In built-up roofing, a weather-resistant (flexible or semiflexible) covering consisting of alternate layers of felt and bitumen, fabricated in a continuous covering and surfaced with aggregate or asphaltic material. [CHEM ENG] **1.** The medium through which the fluid stream is passed for purposes of filtration. **2.** The ion-exchange medium used in dialysis, diffusion, osmosis and reverse osmosis, and electrophoresis. [HISTOL] A thin layer of tissue surrounding a part of the body, separating adjacent cavities, lining cavities, or connecting adjacent structures. { 'mem,brān }

membrane analogy [MECH] A formal identity between the differential equation and boundary conditions for a stress function for torsion of an elastic prismatic bar, and those for the deflection of a uniformly stretched membrane with the same boundary as the cross section of the bar, subjected to a uniform pressure. { 'mem,brān ə,nal·ə·jē }

membrane bone *See* dermal bone. { 'mem,brān ,bōn }

membrane carrier [CYTOL] Any protein that facilitates the movement of small molecules across cell membranes. { 'mem,brān ,kar·ē·ər }

membrane curing *See* membrane waterproofing. { 'mem,brān ,kyůr·iŋ }

membrane distillation [CHEM ENG] A separation method that uses a nonwetting, microporous membrane, with a liquid feed phase on one side and a condensing permeate phase on the other. Also known as membrane evaporation; thermopervaporation; transmembrane distillation. { 'mem,brān ,dis·tə'lā·shən }

membrane evaporation *See* membrane distillation. { 'mem,brān i,vap·ə'rā·shən }

membrane keyboard [COMPUT SCI] A flat keyboard, used with microcomputers and hand-held calculators, that consists of two closely spaced membranes separated by a flat sheet called a spacer with holes corresponding to the keys. { 'mem,brān 'kē,bȯrd }

membrane mimetic chemistry [ORG CHEM] The study of processes and reactions that have been developed by using information obtained from biological membrane systems. { ¦mem,brān mi¦med·ik 'kem·ə·strē }

membrane potential [PHYSIO] A potential difference across a living cell membrane. { 'mem,brān pə,ten·chəl }

membrane separation [CHEM ENG] The use of thin barriers (membranes) between miscible fluids for separating a mixture; a suitable driving force across the membrane, for example concentration or pressure differential, leads to preferential transport of one or more feed components. { 'mem,brān ,sep·ə'rā·shən }

membrane stress [MECH] Stress which is equivalent to the average stress across the cross section involved and normal to the reference plane. { 'mem,brān ,stres }

membrane waterproofing [CIV ENG] Curing concrete, especially in pavements, by spraying a liquid material over the surface to form a solid, impervious layer which holds the mixing water in the concrete. Also known as membrane curing. { 'mem,brān 'wȯd·ər,prüf·iŋ }

membranous glomerulonephritis [MED] A type of glomerulonephritis characterized by thickening of the basement membrane due to deposition of electron-dense material. { 'mem·brə·nəs glə¦mer·yə·lō·ne'frīd·əs }

membranous labyrinth [ANAT] The membranous portion of the inner ear of vertebrates. { 'mem·brə·nəs 'lab·ə,rinth }

membranous pregnancy [MED] Gestation in which there has been a rupture of the amniotic sac and the fetus is in direct contact with the wall of the uterus. { 'mem·brə·nəs 'preg·nən·sē }

membranous urethra [ANAT] The part of the urethra between the two facial layers of the urogenital diaphragm. { 'mem,brə·nəs yů'rē·thrə }

MEMC *See* methoxyethylmercury chloride.

memex [COMPUT SCI] A hypothetical machine described by Vannevar Bush, which would store written records so that they would be available almost instantly by merely pushing the right button for the information desired. { 'me,meks }

memistor [ELEC] Nonmagnetic memory device consisting of a resistive substrate in an electrolyte; when used in an adaptive system, a direct-current signal removes copper from an anode and deposits it on the substrate, thus lowering the resistance of the substrate; reversal of the current reverses the process, raising the resistance of the substrate. { me'mis·tər }

memomotion study [IND ENG] A technique of work measurement and methods analysis using a motion picture camera operated at less than normal camera speed. Also known as camera study; micromotion study. { ¦mem·ō¦mō·shən ,stəd·ē }

memory [COMPUT SCI] Any apparatus in which data may be stored and from which the same data may be retrieved; especially, the internal, high-speed, large-capacity working storage of a computer, as opposed to external devices. Also known as computer memory. [PSYCH] The recollection of past events or sensations, or the performance of previously learned skills without practice. { 'mem·rē }

memory address register [COMPUT SCI] A special register containing the address of a word currently required. { 'mem·rē 'ad,res ,rej·ə·stər }

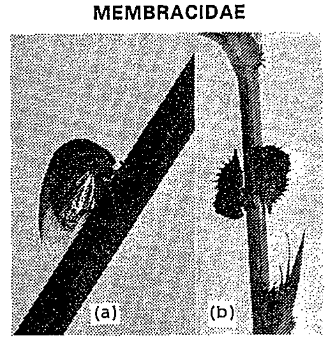
memory bank [COMPUT SCI] A physical section of a computer memory, which may be designed to handle information transfers independently of other such transfers in other such sections. { 'mem·rē ,baŋk }

memory buffer register [COMPUT SCI] A special register in which a word is stored as it is read from memory or just prior to being written into memory. { 'mem·rē 'bəf·ər ,rej·ə·stər }

memory capacity *See* storage capacity. { 'mem·rē kə'pas·əd·ē }

memory card [COMPUT SCI] A small card, typically with dimensions of about 2 × 3 inches (5 × 8 centimeters), that can

MEMBRACIDAE



Membracids on stems. *(a)* Adult. *(b)* Nymphs. *(Courtesy of C. H. Hanson)*

mation can be transmitted; in certain signaling systems, both signals can be the same. { prə'sēd tə si'lekt ˌsig·nəl }

proceed-to-transmit signal [COMMUN] Signal returned from a distant manual switchboard over the backward signaling path, in response to a calling signal, to indicate that the teleprinter of the distant operator is connected to the circuit. { prə'sēd tə tranz'mit ˌsig·nəl }

Procellarian [GEOL] Pertaining to lunar lithologic map units and topographic forms constituting, or closely associated with, the maria. { ˌprō·sə'lar·ē·ən }

Procellariidae [VERT ZOO] A family of birds in the order Procellariiformes comprising the petrels, fulmars, and shearwaters. { ˌprō·sə·lə'rī·əˌdē }

Procellariiformes [VERT ZOO] An order of oceanic birds characterized by tubelike nostril openings, webbed feet, dense plumage, compound horny sheath of the bill, and, often, a peculiar musky odor. { ˌprō·sə·ləˌrī·ə'fȯrˌmēz }

procephalon [INV ZOO] The part of an insect's head that lies anteriorly to the segment in which the mandibles are located. { prō'sef·əˌlän }

procercoid [INV ZOO] The solid parasitic larva of certain eucestodes, such as pseudophyllideans, that develops in the body of the intermediate host. { prō'sərˌkȯid }

process [ANAT] A projection from the central mass of an organism. [COMPUT SCI] To assemble, compile, generate, interpret, compute, and otherwise act on information in a computer. [ENG] A system or series of continuous or regularly occurring actions taking place in a predetermined or planned manner to produce a desired result. { 'präˌses }

process analytical chemistry [ANALY CHEM] A branch of analytical chemistry concerned with quantitative and qualitative information about a chemical process. { 'präˌsəs ˌan·əl'it·i·kəl 'kem·ə·strē }

process analyzer [CHEM ENG] An instrument for determining the chemical composition of the substances involved in a chemical process directly, or for measuring the physical parameters indicative of composition. { 'präˌsəs ˌan·əˌlīz·ər }

process annealing [MET] Softening a ferrous alloy by heating to a temperature close to but below the lower limit of the transformation range and then cooling. { 'präˌsəs əˌnēl·iŋ }

process-bound program *See* CPU-bound program. { 'präˌses ¦bau̇nd 'prō·grəm }

process camera [OPTICS] Large camera used to produce materials for reproduction in printing; permits a large range of enlargement and reduction. { 'präˌsəs ˌkam·rə }

process chart [IND ENG] A graphic representation of events occurring during a series of actions or operations. { 'präˌsəs ˌchärt }

process color [GRAPHICS] Method of reproducing full-color originals such as paintings and color photographs; four-color process plates print in yellow, magenta, cyan, and black. { 'präˌsəs ˌkəl·ər }

process control [ENG] Manipulation of the conditions of a process to bring about a desired change in the output characteristics of the process. { 'präˌsəs kənˌtrōl }

process control chart [IND ENG] A tabulated graphical arrangement of test results and other pertinent data for each production assembly unit, arranged in chronological sequence for the entire assembly. { 'präˌsəs kənˌtrōl ˌchärt }

process control engineering [ENG] A field of engineering dealing with ways and means by which conditions of continuous processes are automatically kept as close as possible to desired values or within a required range. { 'präˌsəs kənˌtrōl ˌen·jəˌnir·iŋ }

process control system [CONT SYS] The automatic control of a continuous operation. { 'präˌsəs kənˌtrōl ˌsis·təm }

process dynamics [ENG] The dynamic response interrelationships between components (units) of a complex system, such as in a chemical process plant. { 'präˌsəs dīˌnam·iks }

process engineering [ENG] A service function of production engineering that involves selection of the processes to be used, determination of the sequence of all operations, and requisition of special tools to make a product. { 'präˌsəs ˌen·jəˌnir·iŋ }

process furnace [CHEM ENG] Furnace used to heat process-stream materials (liquids, gases, or solids) in a chemical-plant operation; types are direct-fired, indirect-fired, and pebble heaters. { 'präˌsəs ˌfər·nəs }

process heater [CHEM ENG] Equipment for the heating of chemical process streams (gases, liquids, or solids); usually refers to furnaces, in contrast to heat exchangers. { 'präˌsəs ˌhēd·ər }

process heat reactor [NUCLEO] A nuclear reactor that produces heat for use in manufacturing processes. { 'präˌsəs ¦hēt rēˌak·tər }

processing [COMMUN] Further handling, manipulation, consolidation, compositing, and so on, of information to convert it from one format to another or to reduce it to manageable or intelligible information. [ENG] The act of converting material from one form into another desired form. { 'präˌses·iŋ }

processing interrupt [COMPUT SCI] The interruption of the batch processing mode in a real-time system when live data are entered in the system. { 'präˌses·iŋ 'int·əˌrəpt }

processing program [COMPUT SCI] Any computer program that is not a control program, such as an application program, or a noncontrolling part of the operating system, such as a sort-merge program or language translator. { 'präˌses·iŋ ¦prō ˌgram }

processing section [COMPUT SCI] The computer unit that does the actual changing of input into output; includes the arithmetic unit and intermediate storage. { 'präˌses·iŋ ˌsek·shən }

process lapse rate [METEOROL] The rate of decrease of the temperature of an air parcel as it is lifted, expressed as $-dT/dz$, where z is the altitude, or occasionally dT/dp, where p is pressure; the concept may be applied to other atmospheric variables, such as the process lapse rate of density. { 'präˌsəs 'laps ˌrāt }

process layout [IND ENG] In a processing plant, the layout of machines, equipment, and locations which groups the same or similar operations. { 'präˌsəs ˌlāˌau̇t }

process lens [OPTICS] A highly corrected, apochromatic lens used for precise color-separation work. { 'präˌsəs ˌlenz }

process-limited *See* processor-limited. { 'präˌsəs ¦lim·əd·əd }

process metallurgy [MET] The branch of metallurgy concerned with the extraction of metals from ore, and with the refining of metals; usually synonymous with extractive metallurgy. { 'präˌsəs ˌmed·əlˌər·jē }

process monitoring [CHEM ENG] The observation of chemical process variables by means of pressure, temperature, flow, and other types of indicators; usually occurs in a central control room. { 'präˌsəs ˌmän·ə·triŋ }

processor [COMPUT SCI] **1.** A device that performs one or many functions, usually a central processing unit. Also known as engine. **2.** A program that transforms some input into some output, such as an assembler, compiler, or linkage editor. { 'präˌses·ər }

processor complex [COMPUT SCI] The central portion of a very large computer consisting of several central processing units working in concert. { 'präˌses·ər ¦kämˌpleks }

processor error interrupt [COMPUT SCI] The interruption of a computer program because a parity check indicates an error in a word that has been transferred to or within the central processing unit. { 'präˌses·ər ¦er·ər ˌint·əˌrəpt }

processor-limited [COMPUT SCI] Property of a computer system whose processing time is determined by the speed of its central processing unit rather than by the speed of its peripheral equipment. Also known as process-limited. { 'präˌses·ər ¦lim·əd·əd }

processor-memory-switch notation *See* PMS notation. { 'präˌses·ər 'mem·rē ˌswich nōˌtā·shən }

processor stack pointer [COMPUT SCI] A programmable register used to access all temporary-storage words related to an interrupt-service routine which was halted when a new service routine was called in. { 'präˌses·ər 'stak ˌpȯint·ər }

processor status word [COMPUT SCI] A word comprising a set of flag bits and the interrupt-mask status. { 'präˌses·ər ¦stad·əs ˌwərd }

process piping [ENG] In an industrial facility, pipework whose function is to convey the materials used for the manufacturing processes. { 'präˌses ˌpīp·iŋ }

process planning [IND ENG] Determining the conditions necessary to convert material from one state to another. { 'präˌses ˌplan·iŋ }

process printing [GRAPHICS] The printing from a series of two or more halftone plates to produce intermediate colors and shades. { 'präˌses ˌprint·iŋ }

process research [SCI TECH] Applied research with a new or improved process in view. { 'präˌses riˌsərch }

process schizophrenia [PSYCH] Schizophrenia having a

posed of large multinucleated histiocytes that contain glycolipids. { rə,tik·yə·lō,his·tē·ō·sə'tō·mə }

reticulopenia *See* reticulocytopenia. { re,tik·yə·lō'pē·nyə }

reticulopodia [INV ZOO] Pseudopodia in the form of a branching network. { rə¦tik·yə·lō'päd·ē·ə }

Reticulosa [PALEON] An order of Paleozoic hexactinellid sponges with a branching form in the subclass Hexasterophora. { rə,tik·yə'lō·sə }

reticulosis [MED] An increase in the number of histiocytes, monocytes, or other reticuloendothelial elements.

reticulospinal tract [ANAT] Nerve fibers descending from large cells of the reticular formation of the pons and medulla into the spinal cord. { rə¦tik·yə·lō'spīn·əl 'trakt }

reticulum [BIOL] A fine network. [VERT ZOO] The second stomach in ruminants. { rə'tik·yə·ləm }

Reticulum [ASTRON] A southern constellation, right ascension 4 hours, declination 60° south. Also known as Net. { rə'tik·yə·ləm }

Reticulum system [ASTRON] A globular cluster or dwarf galaxy near the Large Magellanic Cloud. { ri'tik·yə·ləm ,sis·təm }

retina [COMPUT SCI] In optical character recognition, a scanning device. [ANAT] The photoreceptive layer and terminal expansion of the optic nerve in the dorsal aspect of the vertebrate eye. { 'ret·ən·ə }

retina character reader [COMPUT SCI] A character reader that operates in the manner of the human retina in recognizing identical letters in different type fonts. { 'ret·ən·ə 'kar·ik·tər ,rēd·ər }

retinaculum [INV ZOO] **1.** A clasp on the forewing of certain moths for retaining the frenulum of the hindwing. **2.** An appendage on the third abdominal somite of springtails that articulates with the furcula. { ,ret·ən'ak·yə·ləm }

retinal [BIOCHEM] A carotenoid, produced as an intermediate in the bleaching of rhodopsin and decomposition to vitamin A. Also known as vitamin A aldehyde. { 'ret·ən·əl }

retinal astigmatism [MED] Astigmatism due to changes in the localization of the fixation point. { 'ret·ən·əl ə'stig·mə,tiz·əm }

retinal illuminance [OPTICS] A psychophysiological quantity which is a measure of the brightness of a visual sensation; it is measured in trolands. { 'ret·ən·əl i'lü·mə·nəns }

retinalite [MINERAL] A massive, honey-yellow or greenish serpentine mineral with a waxy or resinous luster; a variety of chrysolite. { 'ret·ən·əl,īt }

retinal pigment *See* rhodopsin. { 'ret·ən·əl 'pig·mənt }

retinal retinitis *See* vascular retinopathy. { 'ret·ən·əl ,ret·ən'īd·əs }

retinasphalt [MINERAL] A light-brown variety of retinite usually found with lignite. { ,ret·ən'a,sfòlt }

retinene [BIOCHEM] A pigment extracted from the retina, which turns yellow by the action of light; the chief carotenoid of the retina. { 'ret·ən,ēn }

retinite [MINERAL] A fossil resin, such as glessite, krantzite, muckite, and ambrite, composed of 6–15% oxygen, lacking succinic acid, and found in brown coals and peat. { 'ret·ən,īt }

retinitis [MED] Inflammation of the retina. { ,ret·ən'īd·əs }

retinitis pigmentosa [MED] A hereditary affection inherited as a sex-linked recessive and characterized by slowly progressing atrophy of the retinal nerve layers, and clumping of retinal pigment, followed by attenuation of the retinal arterioles and waxy atrophy of the optic disks. { ,ret·ən'īd·əs ,pig·mən 'tō·sə }

retinoblastoma [MED] A malignant tumor of the sensory layer of the retina. { ,ret·ən·ō·bla'stō·mə }

retinochoroiditis [MED] Inflammation of the retina and choroid. { ,ret·ən·ō,kòr,òi'dīd·əs }

retinoid [BIOCHEM] The set of molecules composing vitamin A and its synthetic analogs, such as retinal or retinyl acetate. { 'ret·ən,òid }

retinol *See* vitamin A. { 'ret·ən,òl }

retinopathy [MED] Any pathologic condition involving the retina. { ,ret·ən'äp·ə·thē }

retinoschisis [MED] **1.** Separation with hole formation of the layers composing the retina. **2.** A congenital anomaly characterized by cleavage of the retina. { ,ret·ən·ō'ski·səs }

retinula [INV ZOO] The receptor element at the inner end of the ommatidium in a compound eye. { rə'tin·yə·lə }

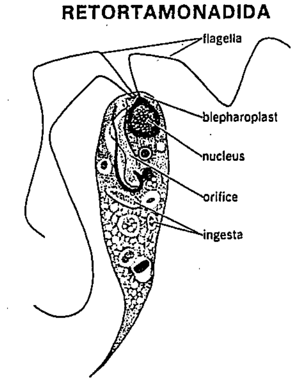
retire [NAV] To move a line of position back, parallel to itself, along a course line to obtain a line of position at an earlier time. { ri'tīr }

retired line of position [NAV] A line of position which has been moved backward along the course line to correspond with a time previous to that at which the line was established. { ri'tīrd 'līn əv pə'zish·ən }

retort [CHEM ENG] **1.** A closed refractory chamber in which coal is carbonized for manufacture of coal gas. **2.** A vessel for the distillation or decomposition of a substance. { ri'tòrt }

Retortamonadida [INV ZOO] An order of parasitic flagellate protozoans belonging to the class Zoomastigophorea, having two or four flagella and a complex blepharoplast-centrosome-axostyle apparatus. { ri'tòr·də·mə'näd·ə·də }

RETORTAMONADIDA



Chilomastix aulastomi.

retouch colors [GRAPHICS] Colors used to correct defects in black-and-white and color photographs; they adhere without crawling and can be used with brushes or airbrush on matte and glossy prints. { 'rē,təch ,kəl·ərz }

retrace *See* flyback. { 'rē,trās }

retrace blanking [ELECTR] Blanking a television picture tube during vertical retrace intervals to prevent retrace lines from showing on the screen. { 'rē,trās ,blaŋk·iŋ }

retrace line [ELECTR] The line traced by the electron beam in a cathode-ray tube in going from the end of one line or field to the start of the next line or field. Also known as return line. { 'rē,trās ,līn }

retracker *See* rerailer. { rē'trak·ər }

retract [MATH] A subset R of a topological space X is a retract of X if there is a continuous map f from X to R, with $f(r) = r$ for all points r of R. { 'rē,trakt }

retractor [ANAT] A muscle that draws a limb or other body part toward the body. [MED] A clawlike instrument for holding tissues away from the surgical field. { ri'trak·tər }

retransmission unit [ELECTR] Control unit used at an intermediate station for feeding one radio receiver-transmitter unit for two-way communication. { ¦rē·tranz'mish·ən ,yü·nət }

retreat [MIN ENG] Workings in the opposite direction of advance work which, when completed, will permit the area to be abandoned as finished. { ri'trēt }

retreater [ENG] A defective maximum thermometer of the liquid-in-glass type in which the mercury flows too freely through the constriction; such a thermometer will indicate a maximum temperature that is too low. { ri'trēd·ər }

retreat gun *See* evening gun. { ri'trēt ,gən }

retrievable inner barrel [ENG] The inner barrel assembly of a wire-line core barrel, designed for removing core from a borehole without pulling the rods. { ri'trēv·ə·bəl 'in·ər 'bar·əl }

retrieve [COMPUT SCI] To find and select specific information. { ri'trēv }

retroaction *See* positive feedback. { ¦re·trō'ak·shən }

retroactive refit *See* retrofit. { ¦re·trō'ak·tiv 'rē,fit }

retrocerebral gland [INV ZOO] Any of various endocrine glands located behind the brain in insects which function in postembryonic development and metamorphosis. { ¦re·trō·sə'rē·brəl 'gland }

retrodirective mirror [OPTICS] **1.** An optical system consisting of two mutually perpendicular plane mirrors; it reflects any beam of light which lies in a plane perpendicular to the mirrors into a direction antiparallel to its original direction. **2.** An optical system consisting of three mutually perpendicular plane mirrors; it reflects any beam of light into a direction antiparallel to its original direction. { ¦re·trō·di'rek·tiv 'mir·ər }

retrofire time [AERO ENG] The computed starting time and duration of firing of retrorockets to decrease the speed of a recovery capsule and make it reenter the earth's atmosphere at the correct point for a planned landing. { 're·trō,fīr ,tīm }

retrofit [ENG] A modification of equipment to incorporate changes made in later production of similar equipment; it may be done in the factory or field. Derived from retroactive refit. { 're·trō,fit }

retroflexion [ANAT] The state of being bent backward. [MED] A condition in which the uterus is bent backward on itself, producing a sharp angle in its longitudinal axis at the junction of the cervix and the fundus. { ¦re·trə'flek·shən }

retrogradation [CHEM] **1.** Generally, a process of deterioration; a reversal or retrogression to a simpler physical form. **2.** A chemical reaction involving vegetable adhesives, which revert to a simpler molecular structure. { ¦re·trō·grā'dā·shən }

retrograde amnesia [MED] Loss of memory for events oc-

interval is equal to the change in storage; it is applied in hydrology to the routing of floods through a reservoir or a reach of a stream; the moisture continuity equation applied to the atmosphere is a modification of this. { 'stȯr·ij i,kwā·zhən }

storage factor *See* Q. { 'stȯr·ij ,fak·tər }

storage fill [COMPUT SCI] Storing a pattern of characters in areas of a computer storage that are not intended for use in a particular machine run; these characters cause the machine to stop if one of these areas is erroneously referred to. Also known as memory fill. { 'stȯr·ij ,fil }

storage hierachy [COMPUT SCI] The sequence of storage devices, characterized by speed, type of access, and size for the various functions of a computer; for example, core storage from programs and data, disks or drums for temporary storage of massive amounts of data, tapes and cards for back up storage. { 'stȯr·ij 'hī·ər,är·kē }

storage integrator [COMPUT SCI] In an analog computer, an integrator used to store a voltage in the hold condition for future use while the rest of the computer assumes another computer control state. { 'stȯr·ij ,int·ə,grād·ər }

storage key [COMPUT SCI] A special set of bits associated with every word or character in some block of storage, which allows tasks having a matching set of protection key bits to use that block of storage. { 'stȯr·ij ,kē }

storage location [COMPUT SCI] A digital-computer storage position holding one machine word and usually having a specific address. { 'stȯr·ij lō,kā·shən }

storage mark [COMPUT SCI] The name given to a point location which defines the character space immediately to the left of the most significant character in accumulator storage. { 'stȯr·ij ,märk }

storage medium [COMPUT SCI] Any device or recording medium into which data can be copied and held until some later time, and from which the entire original data can be obtained. { 'stȯr·ij ,mēd·ē·əm }

storage oscilloscope [ELECTR] An oscilloscope that can retain an image for a period of time ranging from minutes to days, or until deliberately erased to make room for a new image. { 'stȯr·ij ə¦sil·ə,skōp }

storage pool [COMPUT SCI] A collection of similar data storage devices. { 'stȯr·ij ,pül }

storage print [COMPUT SCI] In computers, a utility program that records the requested core image, core memory, or drum locations in absolute or symbolic form either on the line-printer or on the delayed-printer tape. { 'stȯr·ij ,print }

storage protection [COMPUT SCI] Any restriction on access to storage blocks, with respect to reading, writing, or both. Also known as memory protection. { 'stȯr·ij prə,tek·shən }

storage register [COMPUT SCI] A register in the main internal memory of a digital computer storing one computer word. Also known as memory register. { 'stȯr·ij rej·ə·stər }

storage reservoir *See* impounding reservoir. { 'stȯr·ij ,rez·əv,wär }

storage-retrieval machine [CONT SYS] A computer-controlled machine for an automated storage and retrieval system that operates on rails and moves material either vertically or horizontally between a storage compartment and a transfer station. { ¦stȯr·ij ri'trēv·əl mə,shēn }

storage rings [NUCLEO] Annular vacuum chambers in which charged particles can be stored, without acceleration, by a magnetic field of suitable focusing properties; they are used to stretch effectively the duty cycle of a particle accelerator or to produce colliding beams of particles, resulting in a greater possible center of mass energy. { 'stȯr·ij ,riŋz }

storage ripple [COMPUT SCI] A hardware function, used during maintenance periods, which reads or writes zeros or ones through available storage locations to detect a malfunctioning storage unit. { 'stȯr·ij ,rip·əl }

storage routing *See* flood routing. { 'stȯr·ij ,rüd·iŋ }

storage surface [COMPUT SCI] In computers, the surface (screen), in an electrostatic storage tube, on which information is stored. { 'stȯr·ij ,sər·fəs }

storage tank *See* tank. { 'stȯr·ij ,taŋk }

storage time [ELECTR] **1.** The time required for excess minority carriers stored in a forward-biased *pn* junction to be removed after the junction is switched to reverse bias, and hence the time interval between the application of reverse bias and the cessation of forward current. **2.** The time required for excess charge carriers in the collector region of a saturated transistor to be removed when the base signal is changed to cut-off level, and hence for the collector current to cease. [PHYS] *See* decay time. { 'stȯr·ij ,tīm }

storage-to-register instruction [COMPUT SCI] A machine-language instruction to move a word of data from a location in main storage to a register. { 'stȯr·ij tə 'rej·ə·stər in,strək·shən }

storage-to-storage instruction [COMPUT SCI] A machine-language instruction to move a word of data from one location in main storage to another. { 'stȯr·ij tə 'stȯr·ij in,strək·shən }

storage tube [ELECTR] An electron tube employing cathode-ray beam scanning and charge storage for the introduction, storage, and removal of information. Also known as electrostatic storage tube; memory tube (deprecated usage). { 'stȯr·ij ,tüb }

storage-type camera tube *See* iconoscope. { 'stȯr·ij ¦tīp 'kam·rə ,tüb }

store [COMPUT SCI] **1.** To record data into a (static) data storage device. **2.** To preserve data in a storage device. { stȯr }

store and forward [COMMUN] A procedure in data communications in which data are stored at some point between the sender and the receiver and are later forwarded to the receiver. { 'stȯr ən 'fȯr·wərd }

stored-energy welding [MET] Welding by means of energy accumulated electrostatically, electrochemically, or electromagnetically at a low rate. { 'stȯrd ¦en·ər·jē 'weld·iŋ }

stored program [COMPUT SCI] A computer program that is held in a computer's main storage and carried out by a central processing unit that reads and acts on its instructions. { 'stȯrd 'prō,gram }

stored-program computer [COMPUT SCI] A digital computer which executes instructions that are stored in main memory as patterns of data. { 'stȯrd ¦prō,gram kəm'pyüd·ər }

stored-program control [COMMUN] Electronic control of a telecommunications switching system by means of a program of instructions stored in bulk electronic memory. Abbreviated SPC. { 'stȯrd 'prō,gram kən'trōl }

stored-program logic [COMPUT SCI] Program that is stored in a memory unit containing logical commands in order to perform the same processes on all problems. { 'stȯrd 'prō ,gram ,läj·ik }

stored-program numerical control *See* computer numerical control. { 'stȯrd ¦prō,gram nü'mer·ə·kəl kən,trōl }

stored response chain [COMPUT SCI] A fixed sequence of instructions that are stored in a file and acted on by an interactive computer program at a point where it would normally request instructions from the user, in order to save the user the trouble of repeatedly keying the same commands for a frequently used function. Abbreviated SRC. { 'stȯrd ri'späns ,chān }

stored routine [COMPUT SCI] In computers, a series of instructions in storage to direct the step-by-step operation of the machine. { 'stȯrd rü'tēn }

stored word [COMPUT SCI] The actual linear combination of letters (or their machine equivalents) to be placed in the machine memory; this may be physically quite different from a dictionary word. { 'stȯrd 'wərd }

storethrough [COMPUT SCI] The process of updating data in main memory each time the central processing unit writes into a cache. { 'stȯr,thrü }

store transmission bridge [ELEC] Transmission bridge, which consists of four identical impedance coils (the two windings of the back-bridge relay and live relay of a connector, respectively) separated by two capacitors, which couples the calling and called telephones together electrostatically for the transmission of voice-frequency (alternating) currents, but separates the two lines for the transmission of direct current for talking purposes (talking current). { 'stȯr tranz'mish·ən ,brij }

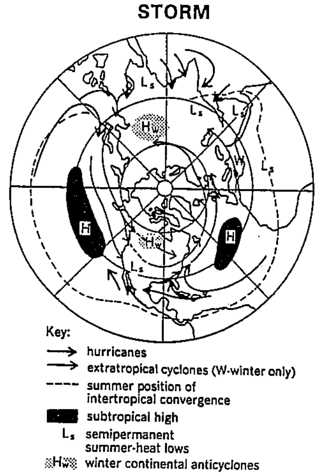
storetrieval system *See* storage and retrieval system. { 'stȯ·ri,trē·vəl ,sis·təm }

stork [VERT ZOO] Any of several species of long-legged wading birds in the family Ciconiidae. { stȯrk }

storm [METEOROL] An atmospheric disturbance involving perturbations of the prevailing pressure and wind fields on scales ranging from tornadoes (0.6 mile or 1 kilometer across) to extratropical cyclones (1.2–1800 miles or 2–3000 kilometers across); also the associated weather (rain storm or blizzard) and the like. { stȯrm }

storm beach [GEOL] A ridge composed of gravel or shingle built up by storm waves at the inner margin of a beach. { 'stȯrm ,bēch }

STORM



Principal tracks of extratropical cyclones and hurricanes with significantly associated features in the Northern Hemisphere.

DEFENDANT'S

EXHIBIT 3

UNITED STATES DEPARTMENT OF COMMERCE
Patent and Trademark Office
Address: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231

SERIAL NUMBER	FILING DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET NO.
08/785,553	12/13/96	WATSON	1960053

B2M1/1009

THE B F GOODRICH COMPANY
PATENT LAW DEPARTMENT
9921 BRECKSVILLE ROAD
BRECKSVILLE OH 44141-3289

amend 01/09/98

EXAMINER	
NOORI, M	
ART UNIT	PAPER NUMBER
2214	

DATE MAILED: 10/09/97

Please find below a communication from the EXAMINER in charge of this application.

Commissioner of Patents

ENTD OCT 24 1997

RECEIVED

OCT 13 1997

Pater

2 - APPLICA

DX 3

PTOL-90 (Rev. 6/84)

Office Action Summary	Application No. 08/785,553	Applicant(s) Watson
	Examiner Max H. Noori	Group Art Unit 2214

☐ Responsive to communication(s) filed on ______________.

☐ This action is **FINAL.**

☐ Since this application is in condition for allowance except for formal matters, **prosecution as to the merits is closed** in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11; 453 O.G. 213.

A shortened statutory period for response to this action is set to expire *3* month(s), or thirty days, whichever is longer, from the mailing date of this communication. Failure to respond within the period for response will cause the application to become abandoned. (35 U.S.C. § 133). Extensions of time may be obtained under the provisions of 37 CFR 1.136(a).

Disposition of Claims

☒ Claim(s) *1-20* is/are pending in the application.

Of the above, claim(s) ______________ is/are withdrawn from consideration.

☐ Claim(s) ______________ is/are allowed.

☒ Claim(s) *1-3, 6, and 9-20* is/are rejected.

☒ Claim(s) *4, 5, 7, and 8* is/are objected to.

☐ Claims ______________ are subject to restriction or election requirement.

Application Papers

☒ See the attached Notice of Draftsperson's Patent Drawing Review, PTO-948.

☐ The drawing(s) filed on ______________ is/are objected to by the Examiner.

☐ The proposed drawing correction, filed on ______________ is ☐approved ☐disapproved.

☐ The specification is objected to by the Examiner.

☐ The oath or declaration is objected to by the Examiner.

Priority under 35 U.S.C. § 119

☐ Acknowledgement is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d).

☐ All ☐ Some* ☐ None of the CERTIFIED copies of the priority documents have been

☐ received.

☐ received in Application No. (Series Code/Serial Number) ______________.

☐ received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

*Certified copies not received: ______________.

☐ Acknowledgement is made of a claim for domestic priority under 35 U.S.C. § 119(e).

Attachment(s)

☒ Notice of References Cited, PTO-892

☒ Information Disclosure Statement(s), PTO-1449, Paper No(s). *5*

☐ Interview Summary, PTO-413

☒ Notice of Draftsperson's Patent Drawing Review, PTO-948

☐ Notice of Informal Patent Application, PTO-152

ENT'D OCT 24 1997

--- SEE OFFICE ACTION ON THE FOLLOWING PAGES ---

DETAILED ACTION

Claim Rejections - 35 USC § 103

1. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

2. Claims 1-2, 9-12 16-17 and 20 are rejected under 35 U.S.C. 103(a) as being unpatentable over Achkar et al., in view of McMurtry.

Regarding claims 1, 9-12, Achkar et al., disclose a rate gyro calibration method and apparatus for three axis stabilized satellite with features of the claimed invention including: installing an attitude determining device on board of said satellite, measuring an attitude of the said satellite, compensating the attitude measurement error (col. 3, line 23). Although, Achkar et al., provide for a rather accurate estimate of the attitude, they do not explicitly recite the utilization of a sensing the installation orientation. Utilization of compensation for installation orientation arrangement on board of mobile craft with respect to a predetermined coordinate system is well known in the art. McMurtry is presented to show such assertion. McMurtry discloses a device for checking the accuracy of coordinate positioning apparatus with components for measuring the coordinate positions. Since Achkar et al., and McMurtry's systems are from the same field of endeavor, the purpose or advantage of McMurtry would have been recognized

as being pertinent in Achkar et al's device. Therefore, it would have been obvious to an artisan or ordinary skill at the time of invention to incorporate a coordinate or orientation positioning apparatus to Achkar et al's device because McMurtry makes it known that utilization of such device for accurate orientation or positioning is notoriously known in the art and is a necessary device for performing an accurate measurement of attitude and other various related parameters (see McMurtry col. 1).

Regarding claim 2, Achkar et al., show the use of three orthogonal axes.

Regarding claims 16-17, and 20, Achkar et al., show the use of various control, processing and logic means, therefore a computer means with its inherent memory and storing capabilities (col 7. lines 22-27).

3. Claims 3, 6, 13-15, 18-19, are rejected under 35 U.S.C. 103(a) as being unpatentable over Achkar et al., in view of McMurtry and further in view of Duncan et al.

Achkar et al., disclose a rate gyro calibration method and apparatus for three axis stabilized satellite; teaching or suggesting features of the claimed invention. Although they show provision for detecting the speed rate in various axes, and as a result acceleration, they do not specifically or directly recite mean for acceleration measurements. Duncan et al., disclose an aircraft gyro system with means to sense acceleration in three axes. It would have been obvious to one of ordinary skill in the art to modify the combination of Achkar/McMurtry with teachings of Duncan et al., to provide for acceleration sensors because Duncan et al., make it clear that

utilization of acceleration sensors are well known in the are and have been extensively described and discussed in the literature (col. 1, lines 36-44)

Regarding claim 13, Duncan et al., show an air craft and all the devices can be installed on an instrument panel.

Regarding claims 14 -15, although Achkar/McMurtry do not specifically mention the type of the attitude determination device, it would have been obvious to one of ordinary skill in the art to modify their device to use either strapdown or gimbal attitude instrument because Duncan et al., also shows that these are well known arrangements in the art (see col. 1, line 46-51).

4. Claims 4-5, 7-8 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

10. The subject matters of claims 4-5 and 7-8 are deemed to be patentable because the prior art fail to disclose and/or make obvious the claimed particular compensation method. Major emphasis is being placed upon the provision of "Determination of static attitude pitch" as a "trigonometric function of a ratio" of acceleration components wherein the "orientation measurement" comprises the "static attitude pitch" and "static attitude roll" in combination with remaining limitations of theses claims and their dependent ones.

5. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure.

The following art are all cited for their notable structure and construction in the related art.

Iddings discloses an all attitude compass.

Watts discloses an aircraft and method for verifying accuracy of positioning apparatus.

Buchler et al., disclose a navigation apparatus with improved attitude determination.

6. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Max H. Noori whose telephone number is (703) 308-5248. The examiner can normally be reached on Monday-Friday from 8:00 AM to 5:30 PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Rich Chilcot, can be reached on (703) 305-4716. The fax number for this group is (703) 308-7382.

Any inquiry of a general nature or relating to the status of this application should be directed to the Group receptionist whose telephone number is (703) 305-4900.

MHN
October 7, 1997

MAX H. NOORI
PATENT EXAMINER
GROUP 2200

Notice of References Cited	Application No. 08/785,553	Applicant(s) Watson
	Examiner Max H. Noori	Group Art Unit 2214	Page 1 of 1

U.S. PATENT DOCUMENTS

	DOCUMENT NO.	DATE	NAME	CLASS	SUBCLASS
A	3,881,258	5/6/75	Iddings	324	247
B	4,212,443	7/15/80	Duncan et al.	244	177
C	4,777,818	10/18/88	McMurtry	73	1.79
D	5,313,410	5/17/94	Watts	73	1.79
E	5,543,804	8/6/96	Buchler et al.	342	357
F	5,562,266	10/8/96	Achkar et al.	73	1.79
G	4,982,504	1/8/91	Söderberg et al.	73	1.79
H					
I					
J					
K					
L					
M					

FOREIGN PATENT DOCUMENTS

	DOCUMENT NO.	DATE	COUNTRY	NAME	CLASS	SUBCLASS
N						
O						
P						
Q						
R						
S						
T						

NON-PATENT DOCUMENTS

	DOCUMENT (Including Author, Title, Source, and Pertinent Pages)	DATE
U		
V		
W		
X		

LC 03414

DEFENDANT'S

EXHIBIT 4

PATENT
Docket No. 1960053

UNITED STATES PATENT AND TRADEMARK OFFICE

In re patent application of:

GARY S. WATSON *et al*

Serial No.: 08/785,553
Filed: 12/13/96

Art Unit: 2214
Examiner: Noori, M.

For: INSTALLATION ORIENTATION OF AN ATTITUDE DETERMINING DEVICE ONBOARD A CRAFT

Assistant Commissioner of Patents
Washington, D.C. 20231

Amendment

Dear Sir:

In response to the Office Action dated October 9, 1997, it is respectfully requested that the claims of the above-identified application be reexamined and reconsidered for allowance based on the following remarks. A petition, including the fee, for a two-month extension of time is attached.

REMARKS

In the last Office Action, claims 1-2, 9-12, 16-17 and 20 were rejected under 35 U.S.C. 103(a) as being unpatentable over Achkar *et al*, in view of McMurtry, both of record. In addition, claims 3, 6, 13-15, 18-19 were rejected under 35 U.S.C. 103(a) as being unpatentable over Achkar *et al*, in view of McMurtry and further in view of Duncan *et al*. Claims 4-5 and 7-8 were objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims. Applicants acknowledge the allowability of dependent claims 4-5 and 7-8, but respectfully traverse the rejections of the remaining claims and support their position with the following remarks.

DX 4

In regard to the obviousness rejection of claims 1-2, 9-12, 16-17 and 20, it is respectfully pointed out that claims 1 and 16 are method claims and the only independent claims of the instant application. Accordingly, claims 2, 9-12 are dependent either directly or indirectly from claim 1 and claims 17 and 20 are dependent either directly or indirectly from independent claim 16. In regard to Achkar *et al*, the Examiner asserts that the rate gyro calibration method and apparatus thereof include features of the claimed invention including: installing an attitude determining device on-board of said satellite, measuring an attitude of the said satellite, and compensating the attitude measurement error (Column 3, line 23). However, the attitude errors of the satellite and the estimated values used for compensation in Achkar *et al* are those concerned with drift and offset or bias errors inherent to the operation of the rate gyros themselves. See particularly Column 1, starting at line 58, where it is stated "it is essential to be able to estimate at any time during the service life of the satellite the drift effecting the rate gyros, or at least the constant part (bias) of such drift." In essence, Achkar is directed to a technique for estimating the bias of a rate sensor while in operation using a star or sun sensor as a long term reference or feed back to correct the bias or offset over time. See Column 2, starting at about line 61. Achkar in no way shape or form addresses the problem of errors in installation orientation and thus, would have no reason or motivation to compensate for such errors in installation.

Further, the Examiner acknowledges that Achkar does not explicitly recite the utilization of sensing the installation orientation (This is because the problem of errors in installation orientation is not addressed.) but, the utilization of compensation for installation orientation arrangement on-board of a mobile craft with respect to a predetermined coordinate system is well known in the art. McMurtry is presented to show such assertion. Applicants have reviewed McMurtry but can find no relationship whatsoever to the installation orientation of an attitude determining device on board a mobile craft. Rather, McMurtry is directed to a machine for measuring the dimensions of work

pieces supported on a table of the machine. McMurtry provides for a support arm and a head which is guided around the work piece attached to the table support for determining dimensions of the work piece. The improvement of McMurtry in this regard is a device for checking the accuracy of the coordinate positioning apparatus. Since Achkar does not teach or even suggest errors in installation orientation of an attitude device on board a mobile craft with respect to the reference coordinate system thereof, there would be no motivation in Achkar for use of any coordinate position apparatus for sensing the installation orientation of such a device. Further, McMurtry does not teach or suggest the installation orientation of an attitude device, the sensing thereof, or the compensation using the sensed installation orientation.

Independent claims 1 and 16 recite, in substance, a method of compensating for installation orientation of an attitude determining device on board a mobile craft comprising the steps of 1) installing the attitude determining device at an unknown orientation with respect to the reference coordinate system of the craft, 2) sensing the installation orientation while the craft is at rest to obtain a static orientation measurement of the device, and 3) compensating the craft attitude measurement of the device with the static orientation measurement. There is no teaching, suggestion or motivation in either Achkar or McMurtry themselves to modify one reference or the other or to combine the reference teachings to render independent claims 1 and 16 obvious in view of the combination thereof. Achkar and McMurtry, either taken individually or in combination, do not teach or suggest the aforementioned claim limitations of independent claims 1 and 16. Accordingly, Applicants contend that independent claims 1 and 16 are patentably distinguishable over the references to Achkar and McMurtry and respectfully request that the obviousness rejection thereof be withdrawn. Since the dependent claims 2, 9-12, 17 and 20 are dependent from either independent claim 1 or independent claim 16 and include all of the limitations of their parent claim they are also considered patentably distinguishable over the references to Achkar and McMurtry and the obviousness rejection thereof should also be withdrawn. There are further claim limitations

in dependent claims 9-12, 17 and 20 which are also clearly patentably distinguishable over the cited references, either taken individually or in combination.

Further in the last Office Action, dependent claims 3, 6, 13-15, 18 and 19 were also rejected under 35 U.S.C. 103(a) as being unpatentable over Achkar *et al* in view of McMurtry and further in view of Duncan *et al*, all of record. Duncan was added to the combination of references to Achkar and McMurtry to show an aircraft gyro system with means to sense acceleration in three axis. The Examiner asserts that it would have been obvious to one of ordinary skill in the art to modify the combination of Achkar/McMurtry with the teachings of Duncan *et al* to provide for acceleration sensors because Duncan *et al* makes it clear that utilization of said sensors are well known in the art and have been extensively described and discussed in the literature.

In response, Applicants have reviewed Duncan and have found that the acceleration sensors of Duncan are used for two purposes - first, for determining the initial conditions for integration of the rate gyros to establish the pitch and roll of the aircraft, e.g. to provide which way is up, and secondly, as a long term reference for attitude errors developed over time *i.e.* offset and bias errors of the rate gyros themselves which are fed back to the rate sensor for compensation. Duncan presumes a precise orientation of the gyro units relative to the aircraft axis, see Column 2, lines 38-39 and also Column 4, lines 36-39. Accordingly, starting from a precision alignment of the attitude determining device with the aircraft axis, there is no need for sensing errors of installation orientation and compensating attitude measurements as a result thereof utilizing accelerometers or any other device for that matter.

Therefore, none of the references cited against the claims, taken individually or in combination, teach, suggest or would motivate anyone towards a method of compensating for unknown installation orientations of an attitude-determining device with respect to the reference

coordinate system of a craft. Since the dependent claims 3, 6, 13-15, 18 and 19 are all dependent from either independent claim 1 or independent claim 16 and include all the limitations of their parent claims, they are considered patentably distinguishable over the references to Achkar, McMurtry and Duncan, either taken individually or in combination, for the same reasons given for their respective parent claims 1 and 16 as noted above.

Duncan does not add anything of substance to that taught by Achkar or McMurtry accept for the use of accelerometers for the purposes of determining initial conditions for the integration of the rate gyros and for long term reference for compensation of drift and bias errors. None of the cited references Achkar, McMurtry or Duncan either taken individually or in combination teach, suggest or would motivate anyone to sense an unknown installation orientation of an attitude determining device, and compensate the craft attitude measurement of the device with the static orientation measurement to obtain attitude information of the crafts' reference coordinate system with respect to the earth frame coordinate system. In fact none of the references even address the issue of errors in installation orientation.

Applicants acknowledge the allowability of dependent claims 4-5 and 7-8, but believe the remaining claims of the instant application are also patentably distinguishable and allowable over the cited references of record. The prior art made of record and not relied upon but considered pertinent to applicants' disclosure was reviewed but found not to affect the patentability of the claims 1-20 of the instant application.

Applicants are submitting herewith by separate correspondence a Supplemental Information Disclosure form including references from a United Kingdom Search report for the counterpart UK patent application.

Accordingly, since the instant application is considered in condition for allowance an early issuance thereof is respectfully solicited.

The commissioner is hereby authorized to charge payment of any additional fees required under 37 CFR 1.16 associated with this communication or credit any overpayment to Deposit Account No. **07-1625**.

Respectfully submitted,

William E. Zitelli

William E. Zitelli
Attorney for Applicant(s)
Registration No. 28,551

Date: March 2, 1998
The B.F.Goodrich Company
9921 Brecksville Road
Brecksville, OH 44141-3289
Telephone: (216) 447-5921

CERTIFICATE OF MAILING

I hereby certify that this correspondence (along with any referred to as being attached or enclosed) is being deposited with the United States Postal Service on the date shown below with sufficient postage as first class mail in an envelope addressed to: COMMISSIONER OF PATENTS AND TRADEMARKS, WASHINGTON, D.C. 20231.

March 2, 1998
Date of Deposit

Depositor: Cynthia L. Kemery
Cynthia L. Kemery

DEFENDANT'S

EXHIBIT 5

UNITED STATES DEPARTMENT OF COMMERCE
Patent and Trademark Office
Address: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, DC 20231

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR		ATTORNEY DOCKET NO.
08/785,553	12/13/96	WATSON	G	1960053

B2M1/0323

THE B F GOODRICH COMPANY
PATENT LAW DEPARTMENT
9921 BRECKSVILLE ROAD
BRECKSVILLE OH 44141-3289

EXAMINER	
NOORI, M	
ART UNIT	**PAPER NUMBER**
2214	

DATE MAILED: 03/23/98

Issue Fee
+
Drawings
06/23/98

ENT'D MAR 30 1998

Please find below and/or attached an Office communication concerning this application or proceeding.

Commissioner of Patents and Trademarks

DX 5

PTO-90C (REV. 2/95)

UNITED STATES DEPARTMENT OF COMMERCE
Patent and Trademark Office

NOTICE OF ALLOWANCE AND ISSUE FEE DUE

B2M1/0323

THE B F GOODRICH COMPANY
PATENT LAW DEPARTMENT
9921 BRECKSVILLE ROAD
BRECKSVILLE OH 44141-3289

APPLICATION NO.	FILING DATE	TOTAL CLAIMS	EXAMINER AND GROUP ART UNIT		DATE MAILED
08/785,553	12/13/96	020	NOORI, M	2214	03/23/98

First Named Applicant: WATSON, GARY S.

TITLE OF INVENTION: METHOD OF COMPENSATING FOR INSTALLATION ORIENTATION OF AN ATTITUDE DETERMINING DEVICE ONBOARD A CRAFT (AS AMENDED)

ATTY'S DOCKET NO.	CLASS-SUBCLASS	BATCH NO.	APPLN. TYPE	SMALL ENTITY	FEE DUE	DATE DUE
3 1960053	073-181.000	B97	UTILITY	NO	$1320.00	06/23/98

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED.

THE ISSUE FEE MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED.

HOW TO RESPOND TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.
If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is changed, pay twice the amount of the FEE DUE shown above and notify the Patent and Trademark Office of the change in status, or

B. If the status is the same, pay the FEE DUE shown above.

If the SMALL ENTITY is shown as NO:

RECEIVED
MAR 25 1998
Patent Law Department

A. Pay FEE DUE shown above, or

B. File verified statement of Small Entity Status before, or with, payment of 1/2 the FEE DUE shown above.

II. Part B-Issue Fee Transmittal should be completed and returned to the Patent and Trademark Office (PTO) with your ISSUE FEE. Even if the ISSUE FEE has already been paid by charge to deposit account, Part B Issue Fee Transmittal should be completed and returned. If you are charging the ISSUE FEE to your deposit account, section "4b" of Part B-Issue Fee Transmittal should be completed and an extra copy of the form should be submitted.

III. All communications regarding this application must give application number and batch number. Please direct all communications prior to issuance to Box ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

YOUR COPY

Notice of Allowability	Application No. 08/785,553	Applicant(s) Watson
	Examiner Max H. Noori	Group Art Unit 2214

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance and Issue Fee Due or other appropriate communication will be mailed in due course.

☒ This communication is responsive to *argument filed on 3/5/98*.

☒ The allowed claim(s) is/are *1-20*.

☐ The drawings filed on ______ are acceptable.

☐ Acknowledgement is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d).

☐ All ☐ Some* ☐ None of the CERTIFIED copies of the priority documents have been

☐ received.

☐ received in Application No. (Series Code/Serial Number) ______.

☐ received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

*Certified copies not received: ______.

☐ Acknowledgement is made of a claim for domestic priority under 35 U.S.C. § 119(e).

A SHORTENED STATUTORY PERIOD FOR RESPONSE to comply with the requirements noted below is set to EXPIRE **THREE MONTHS** FROM THE "DATE MAILED" of this Office action. Failure to timely comply will result in ABANDONMENT of this application. Extensions of time may be obtained under the provisions of 37 CFR 1.136(a).

☐ Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL APPLICATION, PTO-152, which discloses that the oath or declaration is deficient. A SUBSTITUTE OATH OR DECLARATION IS REQUIRED.

☒ Applicant MUST submit NEW FORMAL DRAWINGS

☐ because the originally filed drawings were declared by applicant to be informal.

☒ including changes required by the Notice of Draftsperson's Patent Drawing Review, PTO-948, attached hereto or to Paper No. *8*.

☐ including changes required by the proposed drawing correction filed on ______, which has been approved by the examiner.

☐ including changes required by the attached Examiner's Amendment/Comment.

Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the reverse side of the drawings. The drawings should be filed as a separate paper with a transmittal lettter addressed to the Official Draftsperson.

☐ Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Any response to this letter should include, in the upper right hand corner, the APPLICATION NUMBER (SERIES CODE/SERIAL NUMBER). If applicant has received a Notice of Allowance and Issue Fee Due, the ISSUE BATCH NUMBER and DATE of the NOTICE OF ALLOWANCE should also be included.

Attachment(s)

☐ Notice of References Cited, PTO-892

☒ Information Disclosure Statement(s), PTO-1449, Paper No(s). *3/5/98*

☐ Notice of Draftsperson's Patent Drawing Review, PTO-948

☐ Notice of Informal Patent Application, PTO-152

☐ Interview Summary, PTO-413

☐ Examiner's Amendment/Comment

☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material

☒ Examiner's Statement of Reasons for Allowance

LC 03393

Reasons for Allowance

1. The following is an Examiner's Statement of Reasons for Allowance: The primary reason for allowance of the claims is that prior art neither teach nor fairly suggest the particular combinations of the method of compensating for installation orientation of an attitude sensor as appears in method claims 1 and 16. Major emphasis is being placed upon the provision of an "installing" an "altitude determination device" at an "unknown orientation" and "compensating" the result with a "static orientation measurement" in combination with other limitations of the said independent claim, and its dependent ones.

Any comments considered necessary by applicant must be submitted no later than the payment of the Issue Fee and, to avoid processing delays, should preferably **accompany** the Issue Fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

2. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Max H. Noori whose telephone number is (703) 308-5248. The examiner can normally be reached on Monday-Friday from 8:00 AM to 5:30 PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Rich Chilcot, can be reached on (703) 305-4716. The fax number for this group is (703) 308-7382.

Any inquiry of a general nature or relating to the status of this application should be directed to the Group receptionist whose telephone number is (703) 305-4900.

MHN
March 19, 1998

MAX H. NOORI
PATENT EXAMINER
GROUP 2200

FORM PTO-1449 U.S. DEPARTMENT OF COMMERCE
(Rev. 2-32) PATENT AND TRADEMARK OFFICE

Sheet 1 of 1

OIPE MAR 05 1998 JC21 PATENT & TRADEMARK OFFICE

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use several sheets if necessary)

ATTY. DOCKET NO.	SERIAL NO.
	08 / 785,553
APPLICANT	
Gary S. Watson et al	
FILING DATE	GROUP
12/13/96	2214

RECEIVED MAR 1 9 1998 GROUP 2500

U.S. PATENT DOCUMENTS

EXAMINER INITIAL		DOCUMENT NUMBER							DATE	NAME	CLASS	SUB-CLASS	FILING DATE IF APPROPRIATE
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DEFENDANT'S

EXHIBIT 6

Merriam-Webster's Collegiate® Dictionary

TENTH EDITION

Merriam-Webster, Incorporated
Springfield, Massachusetts, U.S.A.

DX 6

A GENUINE MERRIAM-WEBSTER

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Abbrev

lieutenant — called also *company grade officer;* compare FIELD OFFICER, GENERAL OFFICER

company town *n* (1927) : a community that is dependent on one firm for all or most of the necessary services or functions of town life (as employment, housing, and stores)

company union *n* (1917) : an unaffiliated labor union of the employees of a single firm; *esp* : one dominated by the employer

com·pa·ra·bil·i·ty \\ˌkäm-p(ə-)rə-ˈbi-lə-tē, ÷kəm-ˌpar-ə-\\ *n* (1843) : the quality or state of being comparable

com·pa·ra·ble \\ˈkäm-p(ə-)rə-bəl, ÷kəm-ˈpar-ə-bəl\\ *adj* (15c) **1** : capable of or suitable for comparison **2** : SIMILAR, LIKE ⟨fabrics of ~ quality⟩ — **com·pa·ra·ble·ness** *n* — **com·pa·ra·bly** \\-blē\\ *adv*

comparable worth *n* (1983) : the concept that women and men should receive equal pay for jobs calling for comparable skill and responsibility

com·par·a·tist \\kəm-ˈpar-ə-tist\\ *n* [*comparative* + *-ist*] (1933) : one that uses a comparative method (as in the study of literature)

[1]**com·par·a·tive** \\kəm-ˈpar-ə-tiv\\ *adj* (15c) **1** : of, relating to, or constituting the degree of comparison in a language that denotes increase in the quality, quantity, or relation expressed by an adjective or adverb **2** : considered as if in comparison to something else as a standard not quite attained : RELATIVE ⟨a ~ stranger⟩ **3** : characterized by systematic comparison esp. of likenesses and dissimilarities ⟨~ anatomy⟩ — **com·par·a·tive·ly** *adv* — **com·par·a·tive·ness** *n*

[2]**comparative** *n* (15c) **1 a** : one that compares with another esp. on equal footing : RIVAL **b** : one that makes witty or mocking comparisons **2** : the comparative degree or form in a language

com·par·a·tiv·ist \\kəm-ˈpar-ə-ti-vist\\ *n* (1887) : COMPARATIST

com·par·a·tor \\kəm-ˈpar-ə-tər\\ *n* (1883) : a device for comparing something with a similar thing or with a standard measure

[1]**com·pare** \\kəm-ˈpar, -ˈper\\ *vb* **com·pared; com·par·ing** [ME, fr. MF *comparer,* fr. L *comparare* to couple, compare, fr. *compar* like, fr. *com-* + *par* equal] *vt* (14c) **1** : to represent as similar : LIKEN ⟨shall I ~ thee to a summer's day? —Shak.⟩ **2 a** : to examine the character or qualities of esp. in order to discover resemblances or differences ⟨~ your responses with the answers⟩ **b** : to view in relation to ⟨tall *compared* to me⟩ **3** : to inflect or modify (an adjective or adverb) according to the degrees of comparison ~ *vi* **1** : to bear being compared **2** : to make comparisons **3** : to be equal or alike ⟨nothing ~*s* to you⟩

syn COMPARE, CONTRAST, COLLATE mean to set side by side in order to show differences and likenesses. COMPARE implies an aim of showing relative values or excellences by bringing out characteristic qualities whether similar or divergent ⟨*compared* the convention facilities of the two cities⟩. CONTRAST implies an emphasis on differences ⟨*contrasted* the computerized system with the old filing cards⟩. COLLATE implies minute and critical inspection in order to note points of agreement or divergence ⟨data from districts around the country will be *collated*⟩.

[2]**compare** *n* (1589) : the possibility of comparing ⟨beauty beyond ~⟩; *also* : something with which to be compared ⟨a city without ~⟩

com·par·i·son \\kəm-ˈpar-ə-sən\\ *n* [ME, fr. MF *comparaison,* fr. L *comparation-, comparatio,* fr. *comparare*] (14c) **1** : the act or process of comparing: as **a** : the representing of one thing or person as similar to or like another **b** : an examination of two or more items to establish similarities and dissimilarities **2** : identity of features : SIMILARITY ⟨several points of ~ between the two⟩ **3** : the modification of an adjective or adverb to denote different levels of quality, quantity, or relation

comparison shop *vi* (1970) : to compare prices (as of competing brands) in order to find the best value

[1]**com·part·ment** \\kəm-ˈpärt-mənt\\ *n* [MF *compartiment,* fr. It *compartimento,* fr. *compartire* to mark out in parts, fr. LL *compartiri* to share out, fr. L *com-* + *partiri* to share, fr. *part-, pars* part, share] (ca. 1578) **1** : a separate division or section **2** : one of the parts into which an enclosed space is divided — **com·part·men·tal** \\kəm-ˌpärt-ˈmen-tᵊl, ˌkäm-\\ *adj*

[2]**com·part·ment** \\-ˌment, -mənt\\ *vt* (1918) : COMPARTMENTALIZE

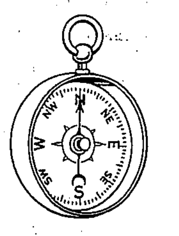
com·part·men·tal·ise *Brit var of* COMPARTMENTALIZE

com·part·men·tal·ize \\kəm-ˌpärt-ˈmen-tᵊl-ˌīz, ˌkäm-\\ *vt* **-ized; -iz·ing** (1925) : to separate into isolated compartments or categories — **com·part·men·tal·i·za·tion** \\-ˌmen-tᵊl-ə-ˈzā-shən\\ *n*

com·part·men·ta·tion \\kəm-ˌpärt-mən-ˈtā-shən, -ˌmen-\\ *n* (1926) : division into separate sections or units

[1]**com·pass** \\ˈkəm-pəs *also* ˈkäm-\\ *vt* [ME, fr. OF *compasser* to measure, fr. (assumed) VL *compassare* to pace off, fr. L *com-* + *passus* pace] (14c) **1** : to devise or contrive often with craft or skill **2** : ENCOMPASS **3 a** : BRING ABOUT, ACHIEVE **b** : to get into one's possession or power : OBTAIN **4** : COMPREHEND — **com·pass·able** \\-pə-sə-bəl\\ *adj*

[2]**compass** *n* (14c) **1 a** : BOUNDARY, CIRCUMFERENCE ⟨within the ~ of the city walls⟩ **b** : a circumscribed space ⟨within the narrow ~ of 21 pages —V. L. Parrington⟩ **c** : RANGE, SCOPE ⟨the ~ of a voice⟩ **2** : a curved or roundabout course ⟨a ~ of seven days' journey —2 Kings 3:9 (AV)⟩ **3 a** : a device for determining directions by means of a magnetic needle or group of needles turning freely on a pivot and pointing to the magnetic north **b** : any of various nonmagnetic devices that indicate direction **c** : an instrument for describing circles or transferring measurements that consists of two pointed branches joined at the top by a pivot — usu. used in pl.; called also *pair of compasses* **4** : DIRECTION 6c ***syn*** see RANGE



compass 3a

[3]**compass** *adj* (1523) : forming a curve : CURVED ⟨a ~ timber⟩

compass card *n* (ca. 1859) : the circular card attached to the needles of a mariner's compass on which are marked the 32 points of the compass and the 360° of the circle

com·pas·sion \\kəm-ˈpa-shən\\ *n* [ME, fr. MF or LL; MF, fr. LL *compassion-, compassio,* fr. *compati* to sympathize, fr. L *com-* + *pati* to bear, suffer — more at PATIENT] (14c) : sympathetic consciousness of others' distress together with a desire to alleviate it ***syn*** see PITY — **com·pas·sion·less** \\-ləs\\ *adj*

[1]**com·pas·sion·ate** \\kəm-ˈpa-sh(ə-)nət\\ *adj* (1587) **1** : having or showing compassion : SYMPATHETIC **2** : granted because of unusual distressing circumstances affecting an individual — used of some military privileges (as leave) — **com·pas·sion·ate·ly** *adv* — **com·pas·sion·ate·ness** *n*

[2]**com·pas·sion·ate** \\-ˈpa-shə-ˌnāt\\ *vt* **-at·ed; -at·ing** (1592) : PITY

compass plant *n* (1848) : a coarse yellow-flowered composite plant (*Silphium laciniatum*) with large pinnatifid leaves that occurs in prairies and along roadsides and railroad tracks of the central U.S.

compass rose *n* (ca. 1891) : a circle graduated to degrees or quarters and printed on a chart to show direction

com·pat·i·ble \\kəm-ˈpa-tə-bəl\\ *adj* [ME, fr. MF, fr. ML *compatibilis,* lit., sympathetic, fr. LL *compati*] (15c) **1** : capable of existing together in harmony ⟨~ theories⟩ **2** : capable of cross-fertilizing freely or uniting vegetatively **3** : capable of forming a homogeneous mixture that neither separates nor is altered by chemical interaction **4** : capable of being used in transfusion or grafting without immunological reaction (as agglutination or tissue rejection) **5** : designed to work with another device or system without modification; *esp* : being a computer designed to operate in the same manner and use the same software as another computer — **com·pat·i·bil·i·ty** \\-ˌpa-tə-ˈbi-lə-tē\\ *n* — **compatible** *n* — **com·pat·i·ble·ness** \\-ˈpa-tə-bəl-nəs\\ *n* — **com·pat·i·bly** \\-blē\\ *adv*

com·pa·tri·ot \\kəm-ˈpā-trē-ət, käm-, -trē-ˌät, *chiefly Brit* -ˈpa-\\ *n* [F *compatriote,* fr. LL *compatriota,* fr. L *com-* + LL *patriota* fellow countryman — more at PATRIOT] (1611) **1** : a person born, residing, or holding citizenship in the same country as another **2** : COMPEER, COLLEAGUE — **com·pa·tri·ot·ic** \\kəm-ˌpā-trē-ˈä-tik, ˌkäm-, *chiefly Brit* -ˌpa-\\ *adj*

[1]**com·peer** \\ˈkäm-ˌpir, käm-ˈ, kəm-ˈ\\ *n* [ME, fr. OF *compere,* lit., godfather, fr. ML *compater,* fr. L *com-* + *pater* father — more at FATHER] (13c) : COMPANION

[2]**compeer** *n* [ME *compere,* fr. OF, fr. L *compar,* fr. *compar,* adj., like — more at COMPARE] (15c) : EQUAL, PEER — **compeer** *vt, obs*

com·pel \\kəm-ˈpel\\ *vt* **com·pelled; com·pel·ling** [ME *compellen,* fr. MF *compellir,* fr. L *compellere,* fr. *com-* + *pellere* to drive — more at FELT] (14c) **1** : to drive or urge forcefully or irresistibly **2** : to cause to do or occur by overwhelming pressure **3** *archaic* : to drive together ***syn*** see FORCE — **com·pel·la·ble** \\-ˈpe-lə-bəl\\ *adj*

com·pel·la·tion \\ˌkäm-pə-ˈlā-shən, -ˌpe-\\ *n* [L *compellation-, compellatio,* fr. *compellare* to address, fr. *com-* + *-pellare* (as in *appellare* to accost, appeal to)] (1603) **1** : an act or action of addressing someone **2** : APPELLATION 1

com·pel·ling \\kəm-ˈpe-liŋ\\ *adj* (1606) : that compels: as **a** : FORCEFUL ⟨a ~ personality⟩ **b** : demanding attention ⟨for ~ reasons⟩ **c** : CONVINCING ⟨no ~ evidence⟩ — **com·pel·ling·ly** *adv*

com·pend \\ˈkäm-ˌpend\\ *n* [ML *compendium*] (1596) : COMPENDIUM

com·pen·di·ous \\kəm-ˈpen-dē-əs\\ *adj* (14c) : marked by brief expression of a comprehensive matter : concise and comprehensive; *also* : COMPREHENSIVE ***syn*** see CONCISE — **com·pen·di·ous·ly** *adv* — **com·pen·di·ous·ness** *n*

com·pen·di·um \\kəm-ˈpen-dē-əm\\ *n, pl* **-di·ums** *or* **-dia** \\-dē-ə\\ [ML, fr. L, saving, shortcut, fr. *compendere* to weigh together, fr. *com-* + *pendere* to weigh — more at PENDANT] (1589) **1** : a brief summary of a larger work or of a field of knowledge : ABSTRACT **2 a** : a list of a number of items **b** : COLLECTION, COMPILATION

com·pen·sa·ble \\kəm-ˈpen(t)-sə-bəl\\ *adj* (1661) : that is to be or can be compensated ⟨a ~ job-related injury⟩ — **com·pen·sa·bil·i·ty** \\kəm-ˌpen(t)-sə-ˈbi-lə-tē, ˌkäm-\\ *n*

com·pen·sate \\ˈkäm-pən-ˌsāt, -ˌpen-\\ *vb* **-sat·ed; -sat·ing** [L *compensatus,* pp. of *compensare,* freq. of *compendere*] *vt* (1646) **1** : to be equivalent to : COUNTERBALANCE **2** : to make an appropriate and usu. counterbalancing payment to **3 a** : to provide with means of counteracting variation **b** : to neutralize the effect of (variations) ~ *vi* **1** : to supply an equivalent — used with *for* **2** : to offset an error, defect, or undesired effect **3** : to undergo or engage in psychological or physiological compensation ***syn*** see PAY — **com·pen·sa·tive** \\ˈkäm-pən-ˌsā-tiv, -ˌpen-; kəm-ˈpen(t)-sə-\\ *adj* — **com·pen·sa·tor** \\ˈkäm-pən-ˌsā-tər, -ˌpen-\\ *n* — **com·pen·sa·to·ry** \\kəm-ˈpen(t)-sə-ˌtōr-ē, -ˌtȯr-\\ *adj*

com·pen·sa·tion \\ˌkäm-pən-ˈsā-shən, -ˌpen-\\ *n* (14c) **1 a** : the act of compensating : the state of being compensated **b** : correction of an organic defect or loss by hypertrophy or by increased functioning of another organ or unimpaired parts of the same organ **c** : a psychological mechanism by which feelings of inferiority, frustration, or failure in one field are counterbalanced by achievement in another **2 a (1)** : something that constitutes an equivalent or recompense ⟨age has its ~*s*⟩ **(2)** : payment to unemployed or injured workers or their dependents **b** : PAYMENT, REMUNERATION — **com·pen·sa·tion·al** \\-shnəl, -shə-nᵊl\\ *adj*

compensatory education *n* (1965) : educational programs intended to make up for experiences (as cultural) lacked by disadvantaged children

[1]**com·pere** *or* **com·père** \\ˈkäm-ˌper\\ *n* [F *compère,* lit., godfather — more at COMPEER] (1914) *chiefly Brit* : the master of ceremonies of an entertainment (as a television program)

[2]**compere** *or* **compère** *vb* **com·pered** *or* **com·pèred; com·per·ing** *or* **com·pèr·ing** *vt* (1933) *chiefly Brit* : to act as compere for ~ *vi, chiefly Brit* : to act as a compere

com·pete \\kəm-ˈpēt\\ *vi* **com·pet·ed; com·pet·ing** [LL *competere* to seek together, fr. L, to come together, agree, be suitable, fr. *com-* + *petere* to go to, seek — more at FEATHER] (1620) : to strive consciously or unconsciously for an objective (as position, profit, or a prize) : be in a state of rivalry

com·pe·tence \\ˈkäm-pə-tən(t)s\\ *n* (1632) **1** : a sufficiency of means for the necessities and conveniences of life ⟨provided his family with a comfortable ~ —Rex Ingamells⟩ **2** : the quality or state of being competent: as **a** : the properties of an embryonic field that enable it to respond in a characteristic manner to an organizer **b** : readiness of bacteria to undergo genetic transformation **3** : the knowledge that enables a person to speak and understand a language — compare PERFORMANCE

com·pe·ten·cy \\-pə-tən(t)-sē\\ *n, pl* **-cies** (1596) : COMPETENCE

com·pe·tent \\ˈkäm-pə-tənt\\ *adj* [ME, suitable, fr. MF & L; MF, fr. L *competent-, competens,* fr. prp. of *competere*] (15c) **1** : proper or rightly pertinent **2** : having requisite or adequate ability or qualities

DEFENDANT'S

EXHIBIT 7

THE AMERICAN HERITAGE DICTIONARY OF THE ENGLISH LANGUAGE

THIRD EDITION

HOUGHTON MIFFLIN COMPANY
Boston · New York

DX 7

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compasses. **3.a.** An enclosing line or boundary; a circumference: *outside the compass of the fence.* See Synonyms at **circumference.** **b.** A restricted space or area: *four huge crates within the compass of the elevator.* **c.** Range or scope, as of understanding, perception, or authority: *"Lacking a coherent intellectual and moral commitment,* [he] *was forced to find his compass in personal experience"* (Doris Kearns Goodwin). See Synonyms at **range.** **—compass** *tr.v.* **-passed, -pass·ing, -pass·es. 1.** To make a circuit of; circle: *The sailboat compassed the island.* **2.** To surround; encircle. See Synonyms at **surround. 3.** To understand; comprehend. **4.** To succeed in carrying out; accomplish. See Synonyms at **reach. 5.** To scheme; plot. **—compass** *adj.* **1.** Forming a curved configuration. **2.** Semicircular. Used of bow windows. [Middle English *compas,* circle, compass, from Old French, from *compasser,* to measure, from Vulgar Latin **compassāre,* to pace off : Latin *com-,* com- + Latin *passus,* step; see PACE¹.] **—com′pass·a·ble** *adj.*

compass card *n.* A freely pivoting circular disk carrying the magnetic needles of a compass and marked with the 32 points of the compass and the 360 degrees of the circle.

com·pas·sion (kəm-păsh′ən) *n.* Deep awareness of the suffering of another coupled with the wish to relieve it. See Synonyms at **pity.** [Middle English *compassioun,* from Late Latin *compassiō, compassiōn-,* from *compassus,* past participle of *compatī,* to sympathize : Latin *com-,* com- + Latin *patī,* to suffer; see **pē(i)-** in Appendix.] **—com·pas′sion·less** *adj.*

com·pas·sion·ate (kəm-păsh′ə-nĭt) *adj.* Feeling or showing compassion; sympathetic. See Synonyms at **humane. —compassionate** (-nāt′) *tr.v.* **-at·ed, -at·ing, -ates.** To pity. **—com·pas′sion·ate·ly** *adv.* **—com·pas′sion·ate·ness** *n.*

compass plant *n.* A perennial herb *(Silphium laciniatum)* in the composite family, native to prairie regions of the Midwest United States and having radiate yellow flower heads and erect, basal, pinnately divided leaves.

com·pat·i·ble (kəm-păt′ə-bəl) *adj.* **1.** Capable of existing or performing in harmonious, agreeable, or congenial combination with another or others: *compatible family relationships.* **2.** Capable of orderly, efficient integration and operation with other elements in a system with no modification or conversion required. **3.** Capable of forming a chemically or biochemically stable system. **4.** Of or relating to a television system in which color broadcasts can be received in black and white by sets incapable of color reception. **5.** *Medicine.* Capable of being grafted, transfused, or transplanted from one individual to another without rejection: *compatible blood.* **—compatible** *n.* A device, such as a computer or computer software, that can be integrated into or used with another device or system of its type. [Middle English, from Medieval Latin *compatībilis,* from Late Latin *compatī,* to sympathize. See COMPASSION.] **—com·pat′i·bil′i·ty, com·pat′i·ble·ness** *n.* **—com·pat′i·bly** *adv.*

com·pa·tri·ot (kəm-pā′trē-ət, -ŏt′) *n.* **1.** A person from one's own country. **2.** A colleague. [French *compatriote,* from Late Latin *compatriōta* : Latin *com-,* com- + Late Latin *patriōta,* countryman; see PATRIOT.] **—com·pa′tri·ot′ic** (-ŏt′ĭk) *adj.*

compd. *abbr.* Compound.

com·peer (kŏm′pîr′, kəm-pîr′) *n.* **1.** A person of equal status or rank; a peer. **2.** A comrade, companion, or associate. [Middle English *comper,* from Old French, from Latin *compār,* equal. See COMPARE.]

com·pel (kəm-pĕl′) *tr.v.* **-pelled, -pel·ling, -pels. 1.** To force, drive, or constrain: *Duty compelled the soldiers to volunteer for the mission.* **2.** To necessitate or pressure by force; exact: *An energy crisis compels fuel conservation.* See Synonyms at **force. 3.** To exert a strong, irresistible force on; sway: *"The land, in a certain, very real way, compels the minds of the people"* (Barry Lopez). [Middle English *compellen,* from Latin *compellere* : *com-,* com- + *pellere,* to drive; see **pel-⁵** in Appendix.] **—com·pel′la·ble** *adj.* **—com·pel′la·bly** *adv.* **—com·pel′ler** *n.*

com·pel·la·tion (kŏm′pə-lā′shən) *n.* **1.** The act of addressing or designating someone by name. **2.** A name; an appellation. [Latin *compellātiō, compellātiōn-,* from *compellātus,* past participle of *compellāre,* to address. See **pel-⁵** in Appendix.]

com·pel·ling (kəm-pĕl′ĭng) *adj.* **1.** Urgently requiring attention: *a host of compelling socioeconomic problems.* **2.** Drivingly forceful: *compelling ambition and egotism.*

com·pend (kŏm′pĕnd′) *n.* A compendium.

com·pen·di·a (kəm-pĕn′dē-ə) *n.* A plural of **compendium.**

com·pen·di·ous (kəm-pĕn′dē-əs) *adj.* Containing or stating briefly and concisely all the essentials; succinct. [Middle English, from Late Latin *compendiōsus,* from Latin *compendium,* a shortening. See COMPENDIUM.] **—com·pen′di·ous·ly** *adv.* **—com·pen′di·ous·ness** *n.*

com·pen·di·um (kəm-pĕn′dē-əm) (-dē-ə)*n., pl.* **-di·ums** or **-di·a. 1.** A short, complete summary; an abstract. **2.** A list or collection of various items. [Latin, a shortening, from *compendere,* to weigh together : *com-,* com- + *pendere,* to weigh; see **(s)pen-** in Appendix.]

com·pen·sa·ble (kəm-pĕn′sə-bəl) *adj.* Being such as to entitle or warrant compensation: *compensable injuries.*

com·pen·sate (kŏm′pən-sāt′) *v.* **-sat·ed, -sat·ing, -sates.** —*tr.* **1.** To offset; counterbalance. **2.** To make satisfactory payment or reparation to; recompense or reimburse: *Management compensated us for the time we worked.* **3.** To stabilize the purchasing power of (a monetary unit) by changing the gold content in order to counterbalance price variations. —*intr.* To serve as or provide a substitute or counterbalance. [Latin *compēnsāre, compēnsāt-* : *com-,* com- + *pēnsāre,* to weigh; see **(s)pen-** in Appendix.] **—com′pen·sa′tive** (kŏm′pən-sā′tĭv, kəm-pĕn′sə-tĭv) *adj.* **—com′pen·sa′tor** *n.* **—com·pen′sa·to′ry** (kəm-pĕn′sə-tôr′ē, -tōr′ē) *adj.*

com·pen·sa·tion (kŏm′pən-sā′shən) *n. Abbr.* **comp. 1.** The act of compensating or the state of being compensated. **2.** Something, such as money, given or received as payment or reparation, as for a service or loss. **3.** *Biology.* The increase in size or activity of one part of an organism or organ that makes up for the loss or dysfunction of another. **4.** *Psychology.* Behavior that develops either consciously or unconsciously to offset a real or imagined deficiency, as in personality or physical ability. **—com′pen·sa′tion·al** *adj.*

com·pere (kŏm′pâr′) *Chiefly British. n.* The master of ceremonies, as of a television entertainment program or a variety show. **—compere** *v.* **-pered, -per·ing, -peres.** —*tr.* To serve as master of ceremonies for. —*intr.* To serve as the master of ceremonies. [French *compère,* from Old French, godfather, companion, from Medieval Latin *compater* : Latin *com-,* com- + Latin *pater,* father; see PATER.]

com·pete (kəm-pēt′) *intr.v.* **-pet·ed, -pet·ing, -petes.** To strive with another or others to attain a goal, such as gaining an advantage or winning a victory. See Synonyms at **rival.** [Late Latin *competere,* to strive together, from Latin, to coincide, be suitable : *com-,* com- + Latin *petere,* to seek; see **pet-** in Appendix.]

com·pe·tence (kŏm′pĭ-təns) *n.* **1.a.** The state or quality of being adequately or well qualified; ability. See Synonyms at **ability. b.** A specific range of skill, knowledge, or ability. **2.** *Law.* The quality or condition of being legally qualified to perform an act. **3.** Sufficient means for a comfortable existence. **4.** *Microbiology.* The ability of bacteria to be genetically transformable. **5.** *Medicine.* The ability to respond immunologically to bacteria, viruses, or other antigenic agents.

com·pe·ten·cy (kŏm′pĭ-tən-se) *n., pl.* **-cies.** Competence.

com·pe·tent (kŏm′pĭ-tənt) *adj.* **1.** Properly or sufficiently qualified; capable: *a competent typist.* **2.** Adequate for the purpose: *a competent performance.* **3.** *Law.* Legally qualified or fit to perform an act. [Middle English, adequate, from Old French, from Latin *competēns, competent-,* present participle of *competere,* to be suitable. See COMPETE.] **—com′pe·tent·ly** *adv.*

com·pe·ti·tion (kŏm′pĭ-tĭsh′ən) *n.* **1.** The act of competing, as for profit or a prize; rivalry. **2.** A test of skill or ability; a contest: *a skating competition.* **3.** Rivalry between two or more businesses striving for the same customer or market. **4.** A competitor: *The competition has cornered the market.* **5.** *Ecology.* The simultaneous demand by two or more organisms for limited environmental resources, such as nutrients, living space, or light.

com·pet·i·tive (kəm-pĕt′ĭ-tĭv) *adj.* **1.** Of, involving, or determined by competition: *competitive games.* **2.** Liking competition or inclined to compete: *a highly competitive sales representative.* **3.** *Biochemistry.* Relating to the inhibition of enzyme activity that results from the reversible combination of an enzyme with an alternate compound and prevents normal substrate binding. **—com·pet′i·tive·ly** *adv.* **—com·pet′i·tive·ness** *n.*

com·pet·i·tor (kəm-pĕt′ĭ-tər) *n.* One that competes with another, as in sports or business; a rival.

Com·piégne (kŏmp-yān′, kôɴ-pyĕn′yə). A city of northern France on the Oise River northeast of Paris. The armistice ending World War I was signed in a railroad car in a nearby forest on November 11, 1918. Adolf Hitler demanded that the same car be used for the formal surrender of France in World War II on June 22, 1940. Population, 40,384.

com·pi·la·tion (kŏm′pə-lā′shən) *n. Abbr.* **comp. 1.** The act of compiling. **2.** Something, such as a set of data, a report, or an anthology, that is compiled.

com·pile (kəm-pīl′) *tr.v.* **-piled, -pil·ing, -piles. 1.** To gather into a single book. **2.** To put together or compose from materials gathered from several sources: *compile an encyclopedia.* **3.** *Computer Science.* To translate (a program) into machine language. [Middle English *compilen,* from Old French *compiler,* probably from Latin *compīlāre,* to plunder : *com-,* com- + *pīla,* heap (of stones), pillar.]

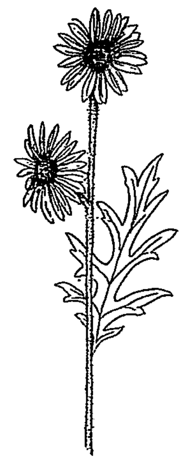
com·pil·er (kəm-pī′lər) *n. Abbr.* **comp. 1.** One that compiles: *a compiler of anthologies.* **2.** *Computer Science.* A program that translates another program written in a high-level language into machine language so that it can be executed.

com·pla·cence (kəm-plā′səns) *n.* **1.** Contented self-satisfaction. **2.** Total lack of concern.

com·pla·cen·cy (kəm-plā′sən-sē) *n.* **1.** A feeling of contentment or self-satisfaction, especially when coupled with an unawareness of danger or trouble. **2.** An instance of contented self-satisfaction.

com·pla·cent (kəm-plā′sənt) *adj.* **1.** Contented to a fault; self-satisfied and unconcerned: *He had become complacent after years of success.* **2.** Eager to please; complaisant. [Latin *complacēns, complacent-,* present participle of *complacēre,* to please : *com-,* intensive pref.; see COM— + *placēre,* to please; see **plāk-¹** in Appendix.] **—com·pla′cent·ly** *adv.*

com·plain (kəm-plān′) *intr.v.* **-plained, -plain·ing, -plains. 1.** To express feelings of pain, dissatisfaction, or resentment. **2.** To make a formal accusation or bring a formal charge. [Middle



compass plant
Silphium laciniatum

ă pat	oi boy
ā pay	ou out
âr care	ŏŏ took
ä father	ōō boot
ĕ pet	ŭ cut
ē be	ûr urge
ĭ pit	th thin
ī pie	*th* this
îr pier	hw which
ŏ pot	zh vision
ō toe	ə about, item
ô paw	♦ regionalism

Stress marks: **′** (primary); ′ (secondary), as in dictionary (dĭk′shə-nĕr′ē)

DEFENDANT'S

EXHIBIT 8

EXHIBIT DX 8: PROPOSED CLAIM CONSTRUCTION CHART

Claim language	L-3 Avionic's Construction	Avidyne's Construction
(Claim 1 and 16): Attitude determining device	A piece of equipment that determines angular orientation relative to the earth frame and is used to establish the attitude of a craft.	A device that includes gravity and motion sensors and a processor for processing the output of the sensors to determine attitude.
(Claim 1 and 16): Compensating for installation orientation of an attitude determining device	Adjusting to neutralize the effect of the orientation of an attitude determining device as installed.	No Definition.
(Claim 1 and 16): Sensing the installation orientation of said attitude determining device with respect to said earth frame coordinate system when said craft is at rest to obtain a static orientation measurement of said device.	Detecting an angular orientation with the installed attitude determining device relative to earth frame while the craft is not moving to obtain a static orientation measurement of said device.	Detecting the angular position of the installed attitude determining device relative to earth frame while the craft is not moving to obtain a static orientation measurement of said device.
(Claim 1 and 16): Measuring an attitude of said mobile craft with said attitude determining device	Using the attitude determining device to measure an angular orientation of the mobile craft.	Using the processor of the attitude determining device to process the output of the sensors of the attitude determining device to obtain the uncompensated attitude of the mobile craft.
(Claim 1): Compensating said craft attitude measurement of said device with said static orientation measurement to obtain attitude information of said craft's reference coordinate system with respect to said earth frame coordinate system.	Using the static orientation measurement to neutralize the craft attitude measurement for the installation orientation of the attitude determining device to obtain an orientation of the craft relative to the earth.	Applying the said static orientation measurement determined in said sensing step to the uncompensated attitude of the craft determined in said measuring step to mathematically modify the uncompensated attitude of the craft determined in said measuring step to thereby adjust for a difference between that measured attitude of the craft and the craft's actual attitude relative to the earth.
(Claim 16): Storing said static orientation measurement in a memory	Retaining static orientation measurement data within the attitude determining device.	Persistently retaining the static orientation measurement in a memory.
(Claim 16): Retrieving said static orientation measurement from said memory to a processor of said device.	Providing static orientation measurement data to an electronic computational device within the attitude determining device.	Obtaining the previously stored static orientation measurement and feeding it to the processor of the attitude determining device.
(Claim 16): Compensating said craft attitude measurement with said retrieved static orientation measurement in said processor to obtain attitude information of said craft's reference coordinate system with respect to said earth frame coordinate system.	Using the static orientation measurement data in an electronic computational device to neutralize the craft attitude measurement for the installation orientation of the attitude determining device to obtain an orientation of the craft relative to the earth.	Applying the retrieved said static orientation measurement determined in said sensing step to the uncompensated attitude of the craft determined in said measuring step in said processor to mathematically modify the uncompensated attitude of the craft determined in said measuring step to thereby adjust for a difference between that measured attitude of the craft and the craft's actual attitude relative to the earth.

DX 8

DEFENDANT'S

EXHIBIT 9

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
School of Engineering Faculty Personnel Record

Date: August 14, 2006

Name: Jonathan P. How
Department: Aeronautics and Astronautics

1. **Date of Birth:** January 14, 1965
2. **Citizenship:** U.S. Citizen
3. **Education:**

School	Degree	Date
Univ. of Toronto	B.A.Sc.	1987
MIT	S.M.	1989
MIT	Ph.D.	1993

4. **Title of Thesis for Most Advanced Degree:**
   Robust Control Design with Real Parameter Uncertainty using Absolute Stability Theory.

5. **Principal Fields of Interest:**
   Navigation and Control: GPS sensing for navigation and control of formation flying spacecraft; trajectory optimization and activity planning for multiple vehicles; and experimental and theoretical robust control.

6. **Name and Rank of Other Department Faculty in the Same Field:**
   John Deyst, Professor
   John Hansman, Professor
   Steve Hall, Professor
   David Miller, Associate Professor
   Brian Williams, Associate Professor

7. **Name and Rank of Faculty in Other Departments in the Same Field:**
   M. A. Dahleh, Professor (EE)
   J.-J. Slotine, Professor (ME)
   A. Megretski, Associate Professor (EE)
   D. Trumper, Associate Professor (ME)

8. **Non-MIT Experience (including military service):**

Employer	Position	Beginning	Ending
Aeronautics and Astronautics Department Stanford Univ.	Asst. Prof.	Sept. 94	Mar. 00

9. **History of MIT Appointments:**

Rank	Beginning	Ending
Postdoctoral Associate	Feb. 93	Aug. 94
Associate Professor (tenured in May 2003)	Apr. 00	present

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10. **Consulting Record:**

Firm	Beginning	Ending
CSA Engineering, Palo Alto, CA	Sept. 96	Mar. 00

11. **Department and Institute Committees, Other Assigned Duties:**

Beginning	Ending	Activity
Qualifying Exam Comm., Dept rep at numerous defenses	1/01	Present
Associate chair of Graduate Committee	1/01	12/01
Curriculum development – Capstone lead	6/01	1/02
Space Evaluation Committee	1/02	6/02
Educational CDIO workshop at KTH	1/02	1/02
Departmental Space Committee	2/02	12/05
Qualifying Exam Redesign Committee	9/03	12/05
Departmental Division Redesign Committee	2/04	12/05
Co-lead of the Information Technology Sector	3/06	Present

12. **Professional service:**

- Editorial Board – Elsevier Astrodynamics Books Series ('05 –)
- Associate Editor – AIAA Journal of Guidance Control and Dynamics ('01 – '04)
- NSF Panel Review (Civil and Mechanical Systems) ('05, '06)
- International Federation of Automatic Control (IFAC) Technical Committee on Aerospace ('01 –)
- IEEE Aerospace Controls Technical Committee ('04 –)
- Executive Board - Collaborative Center of Control Science (Ohio State Univ.) ('02 –)
- SAB Readiness Review Board member for Air Force Research Lab/Vehicles Directorate (AFRL)/VA ('03 & '05)
- Gravitational Wave Visiting Comm. GSFC Lab. of High Energy Astrophysics ('04,'05)
- Technology readiness review for Laser Interferometer Space Antenna (LISA) ('03 – '04)
- Review panel for Telecommunications and Mission Operations Directorate at JPL ('00)
- Autonomy Integrate Product Development Team for the NASA New Millennium Program ('95 – '00)
- Reviewer for IEEE (American Control Conf.; Conf. on Decision and Control; and Transactions on Automatic Control), the ASME, IFAC (Automatica), and AIAA (Journal of Guidance, Control, and Dynamics; Guidance, Navigation, and Control Conf.)
- Conference session chairs: International Federation of Automatic Control '96, Conference on Decision and Control ('97,'98,'05), American Control Conference ('98,'99,'01,'02,'05, '06), Institute of Navigation National Technical Meeting '00
- Program Committee for IEEE American Control Conference 2005, 2006
- Sub-panel on the *Future Directions in Control and Dynamical Systems* regarding Aerospace/Transportation Systems, ('00 – '02)
- Short course on Active Vibration Isolation (with Prof. Debra) at the *Conference for the American Society of Precision Engineering* ('95 – '97)

- Member of DARPA Information Science and Technology summer group on "Distributed Information Systems for MEMS" ('95)

13. **Awards Received:**

2002 Institute of Navigation **Burka Award** for outstanding achievement in the preparation of papers contributing to the advancement of navigation and space guidance.

2006–2008	Raymond L. Bisplinghoff Fellow for MIT Aero/Astro Department
2000–2002	Boeing Associate Professor, MIT
1997–1999	Charles Powell Faculty Scholar, Stanford Univ.
1995	NASA Certificate of Appreciation for MACE
1994–1997	Davis Faculty Scholar, Stanford University
1987–1991	NSERC *1967* Science and Eng. Fellowship (Canada)

Numerous best presentation in session awards – Institute of Navigation ('96, '97, '98, '02), American Control Conference ('98, '00, '01, '02, '04, '05), AIAA Guidance, Navigation, and Control Conference '01, AIAA Conference on Unmanned Air Vehicles '04

14. **Current Organization Membership:**

- Associate Fellow of American Institute Aeronautics and Astronautics (AIAA).
- Senior Member of Institute of Electrical and Electronics Engineers (IEEE)
- Member of Institute of Navigation (ION)

15. **Patents and Patent Applications Pending:**

Indoor Multi-Vehicle Flight Testbed for Fault Isolation, Detection and Recovery. Submitted for evaluation June 2006.

16. **Professional Registration:** N/A

17. **Major New Products, Processes, Designs, or Systems:**

- Robust control design process for uncertain flexible systems, as implemented on the Middeck Active Control Experiment (MACE). The resulting tools combined system and uncertainty modeling with advanced robust control design and analysis techniques in a MATLAB package that required minimal user input. These CAD tools were the precursor to the *ControlForge* software now sold by Mide Technology Corp.
- Indoor Absolute Navigation System using pseudolites and a modified GPS receiver, as delivered to NASA JSC. These pseudolites and receiver were designed to replicate the GPS environment in an indoor clean room, thereby allowing tests to be performed on the AERCam vehicle during prototype development and, in the future, on the flight vehicle prior to launch into LEO.
- Mixed-integer Linear Programming algorithms for UAV path planning with obstacle and collision constraints. These algorithms have recently been adopted by Northrop Grumman to demonstrate nap-of-the-earth path planning for a team of helicopters.

1. Teaching & Educational Contributions of Jonathan P. How

Teaching Experience

Term	Subject Number	Title	Role	Course type	Evaluation given	New course
		MIT				
Fall93	16.341	Multivariable Control design	Recitation Inst.	Lecture	Yes	
		Stanford				
FQ94	E207a	Introduction to control design	Professor	Lecture	Yes	
SQ95	E207c	Modern control II	Professor	Lecture	Yes	√
FQ95	E208a	Linear systems theory	Professor	Lecture	Yes	√
WQ96	E208b	Modern control I	Professor	Lecture	Yes	√
SQ96	E208c	Modern control II	Professor	Lecture	Yes	√
SQ96	AA274	Robust and optimal control	Professor	Lecture	Yes	√
FQ96	E205	Introduction to control design	Professor	Lecture	Yes	√
WQ97	E210a	Robust and optimal control	Professor	Lecture	Yes	√
SQ97	E208c	Modern control II	Professor	Lecture	Yes	
FQ97	E211	System Identification	Professor	Lecture	Yes	√
WQ98	E210a	Robust and optimal control	Professor	Lecture	Yes	
SQ98	AA271a	Dynamics and Control of Aircraft and Spacecraft	Professor	Lecture	Yes	√
FQ98	E205	Introduction to control design	Professor	Lecture	Yes	
SQ99	AA271a	Dynamics and Control of Aircraft and Spacecraft	Professor	Lecture	Yes	
FQ99	E211	System Identification	Professor	Lecture	Yes	
WQ00	E210a	Robust and optimal control	Professor	Lecture	Yes	
		MIT				
ST01	16.61	Dynamics of Aerospace Systems	Professor	Lecture	Yes	√
FT01	16.31	Feedback Control	Professor	Lecture	Yes	√
ST02	16.61	Dynamics of Aerospace Systems	Professor (joint) in charge	Lecture	Yes	
FT02	16.982	Advanced Estimation for GPS and Inertial Navigation	Professor (joint) in charge	Lecture	Yes	√
FT02	16.A45	Physics of Racing Freshman seminar	Professor	Freshman Seminar	Yes	√
ST03	16.61	Dynamics of Aerospace Systems	Professor (joint) In charge	Lecture	Yes	
FT03	16.82	Flight Vehicle Development (CDIO)	Professor (joint) in charge	Design	Yes	√
ST04	16.821	Flight Vehicle Development (CDIO)	Professor (joint) in charge	Design	Yes	√
ST04	16.324	Advanced Estimation for GPS	Professor (joint) in charge	Lecture	Yes	√
FT04	16.333	Flight Dynamics	Professor	Lecture	Yes	√
FT05	16.333	Flight Dynamics	Professor	Lecture	Yes	
ST06	16.323	Principles of Optimal Control	Professor	Lecture	Yes	√

2. Teaching Evaluation Data

Term	Subject Number	Total # students registered	Total # survey response	Survey form used	Instructor Teaching Quality Average	Overall Course Quality Average
		MIT			MIT Question 5 **(see note: 5-best → 1-worst)**	MIT Question 110
FT01	16.31	16	9	AA	4.78/5	4.89/5
ST02	16.61	16	11	AA	4.64/5	4.64/5
FT02	16.982	8	4	AA	4.25/5	5.00/5
ST03	16.61	9	3	AA	4.50/5	4.67/5
FT03	16.82	14	13	AA	3.69/5	4.23/5
ST04	16.821	13	3	AA	2.67/5	3.67/5
ST04	16.324	10	3	AA	4.00/5	4.33/5
FT04	16.333	13	6	AA	5.00/5	4.67/5
FT05	16.333	12	5	AA	4.20/5	4.20/5
ST06	16.323	16	7	AA	4.71/5	4.71/5

MIT Question 5 in "The Instructors" section on the Aero/Astro course evaluation asks

Overall, Professor How contributes to my learning:

(5) Strongly Agree
(4) Agree
(3) Neutral
(2) Disagree
(1) Strongly Disagree

MIT Question 110 in "The Subject" section on the Aero/Astro course evaluation asks

Overall, the subject is worthwhile:

(5) Strongly Agree
(4) Agree
(3) Neutral
(2) Disagree
(1) Strongly Disagree

3. Other Educational Contributions

My teaching philosophy focuses on providing students with sound theoretical training motivated by real-world applications and examples from my research. I have found that an approach of constantly re-examining and revising course content to keep it fresh, obtaining real-time feedback from students (through muddy cards and probing synthesis questions at the beginning of each lecture), and empowering students to be more than mere scribes (through distribution of each lecture's slides) improves the quality of my lectures, the degree of understanding and communication, and students' engagement in sometimes highly technical material. Example lectures for a first-year graduate-level control course are available for evaluation.

My commitment to teaching has been demonstrated through the variety of graduate- and undergraduate-level courses on basic and advanced control, dynamics, and flight dynamics and control that I have developed and taught at both Stanford University and MIT.

Soon after my arrival at Stanford, I revitalized the three-course control sequence taken by all first-year graduate students in the School of Engineering. This included the development of a new first course that emphasized both classical and modern techniques, with a focus on teaching students how to design good controllers using either approach. I also reorganized the control laboratory and secured funding for several mechanical experiments for these first-year courses. To bridge the gap between course work and research, I devised two new robust control and system identification courses for advanced graduate students.

At MIT I started a new course on the dynamics of aerospace vehicles for undergraduates who have completed Unified. This course had two key learning objectives: (i) developing a clear and systematic approach to solving general dynamics problems; and (ii) cultivating an intuitive understanding of complex 3D rotational motion. Student feedback, both informally and through formal course evaluations, was very positive. The material is available on the MIT Open Courseware page: Aerospace Dynamics - Junior level, second course on dynamics. I also combined my interests in innovative applications of GPS with my passion for auto racing to become the faculty leader for a Freshman Seminar entitled "The Physics of Automobile Racing". Fall 2004, I completely revised the MIT course on aircraft dynamics and control, with a renewed emphasis on simulation, vehicle dynamics modeling, and control design. The Fall 2004 course material has been added to the OCW page Aircraft Stability and Control. The student response was extremely positive, with an instructor rating of 5 out of 5 and anonymous comments that included:

> *Professor How is one of the best overall instructors at MIT. His lectures and notes are well-organized and thorough and he effectively develops intuition of the subject matter in his students.*

and

> *The lectures and notes were superb. Professor How prepares well for his classes.*

This past semester I revised the optimal control course with a new emphasis on solution methods. While the course was new material, the student feedback was very positive.

> *Lectures were very clear and organized. Prof. How taught in a clear way so that the difficult concepts made sense. It was an excellent course.*

As my record demonstrates, I have enjoyed working closely with graduate and undergraduate researchers since my time as a PostDoc. At Stanford, I maintained a research group of 10–15 students clustered in smaller working groups focused on specific projects. While that approach was an effective way of handling a large research team, I found that it limited my intellectual interaction with individual students. At MIT I have deliberately reduced my research group to 8 students, thereby allowing me to work more closely with each student. The move to MIT also enabled me to work more closely with undergraduates, and I have had a total of 15 UROPs (undergraduate research opportunity program) working on my UAV testbed. The success of my students is represented by the 19 "best presentation in session" awards at conferences and by the degree to which they have been in demand by various companies, government agencies, and university faculties.

Publications of Jonathan P. How

1. **Books**
2. **Papers in Refereed Journals**

2.1 S. R. Hall, E. F. Crawley, J. P. How, and B. Ward, "A Hierarchic Control Architecture for Intelligent Structures," AIAA *Journal Guidance, Control, and Dynamics,* May-June 1991, **14**, 3, pp. 503-512.

2.2 J. P. How, and S. R. Hall, "Local Control Design Methodologies for a Hierarchic Control Architecture," AIAA *Journal Guidance, Control, and Dynamics*, May-June 1992, **15**, 3, pp. 654–663.

2.3 J. P. How, S. R. Hall, and W. Haddad "Robust Controllers for the Middeck Active Control Experiment using Popov Controller Synthesis," IEEE *Transactions on Control System Technology*, Vol. 2, June, 1994, pp. 73–87.

2.4 J. P. How, W. Haddad, and S. R. Hall, "Application of Popov Controller Synthesis to Benchmark Problems with Real Parametric Uncertainty," AIAA *Journal Guidance, Control, and Dynamics*, Vol. 17, No. 4, July–August 1994, pp. 759-768.

2.5 W. Haddad, J. P. How, and S. R. Hall, and Bernstein, D. S., "Extensions of Mixed-μ Bounds to Monotonic and Odd Monotonic nonlinearities Using Absolute Stability Theory," *Int. Journal of Control,* Nov. 1994, Vol.60, No.5, p. 905-951.

2.6 S. Grocott, J. P. How, D. MacMartin, Liu K., and Miller D. W., "Robust Control Design and Implementation on the Middeck Active Control Experiment (MACE)," AIAA *J. Guidance, Control, and Dynamics,* Nov.–Dec. 1994, **17**, 6, pp. 1163-1170.

2.7 J. P. How and D. Miller, "Development of On-orbit Predictions for the Middeck Active Control Experiment (MACE)," IFAC *Journal on Control Engineering Practice*, Vol. 3, No. 8, Aug., 1995, pp. 1105-11.

2.8 J. P. How, E. G. Collins, Jr., and W. Haddad, "Optimal Popov Analysis and Synthesis for Systems with Real Parametric Uncertainties," IEEE *Trans. on Control Systems Technology*, Vol. 4, No. 2, March, 1996, pp. 200–207.

2.9 J. P. How and D. Miller, "Assessment of Modelling and Robust Control Techniques for Future Spacecraft: Middeck Active Control Experiment," *Journal of the Astronautical Sciences*, Vol 44, No. 2, April-June, 1996, pp. 223–240.

2.10 J. P. How, R. Glaese, S. Grocott, and D. Miller, "Finite Element Model Based Robust Controllers for the MIT Middeck Active Control Experiment (MACE)," IEEE *Trans. on Control Systems Technology*, Vol. 5, No. 1, Jan, 1997, pp. 110–118.

2.11 S. C. Grocott, J. P. How, and D. Miller, "Experimental Comparison of Robust $\mathcal{H}_2$ Control Techniques for Uncertain Structural Systems," AIAA *Journal Guidance, Control, and Dynamics,* Vol 20, No. 3, May-June, 1997, pp. 611-613.

2.12 Teague, H., J. P. How, and Parkinson, B., "Techniques for Real-time Control of Flexible Structures using GPS," *The Journal of The Institute Of Navigation,* Vol. 44, No. 2, pp. 215–230, Summer, 1997. ** [1]

[1] ** Denotes paper containing research done with my students.

2.13 D. Miller, J. P. How, K. Liu, M. Campbell, R. Glaese, S. Grocott, and T. Tuttle, "Flight Results from the Middeck Active Control Experiment (MACE)," AIAA *Journal,* March, 1998, pp. 432-440.

2.14 D. Banjerdpongchai and J. P. How,"Parametric Robust H_2 Control Design with Generalized Multipliers via LMI synthesis," *International Journal of Control*, Vol 70, No. 3, May, 1998, pp. 481–503. **

2.15 H. Teague, J. P. How, and B. Parkinson, "Attitude and Vibration Control of Flexible Structures Using GPS: Methods and Experimental Results," *AIAA Journal Guidance, Control, and Dynamics,* Sept-Oct, 1998, pp. 673–683. **

2.16 T. Corazzini, A. Robertson, J. C. Adams, A. Hassibi, and J. P. How, "GPS Sensing for Spacecraft Formation Flying," Fall issue of the *The Journal of The Institute Of Navigation,* Vol, 45, No. 3, 1998, pp. 195–208. **

2.17 M. Campbell, J. P. How, S. Grocott, and D. Miller, "On-orbit Closed-loop Control Results for MACE," *AIAA Journal Guidance, Control, and Dynamics,* Vol 22, No. 2, March 1999, pp. 267–277.

2.18 T. E. Paré and J. P. How, "Hybrid $\mathcal{H}_2$ Control Design for Vibration Isolation," in the *Journal of Sound and Vibration,* Volume 226(1), Sept. 1999, pages 25-39. **

2.19 S. Lim, H. D. Stevens, and J. P. How, "Input Shaping Design for Multi-Input Flexible Systems," *ASME Journal of Dynamic Systems, Measurement, and Control,* Vol. 121, No. 3, Sept, 1999, pp.443-447. **

2.20 E. Olsen, C.-W. Park, and J. P. How, "3D Formation Flight using Differential Carrier-phase GPS Sensors," *Navigation* Journal of the Institute of Navigation, Spring, 1999, Vol. 146, No. 1, pp. 35–48. **

2.21 A. Hassibi, J. P. How, and S. Boyd, "Low-Authority Controller Design via Convex Optimization", the AIAA *Journal Guidance, Control, and Dynamics,* Vol. 22, No. 6, Nov.-Dec., 1999, pp. 862–872. **

2.22 D. Banjerdpongchai, and J. P. How, "Parametric Robust H_2 Control Design Using LMI Synthesis", the AIAA *Journal Guidance, Control, and Dynamics*, Vol. 23, No. 1, Jan.-Feb., 2000, pp. 138–142. **

2.23 B. Sayyar-Rodsari, J. P. How, B. Hassibi, and A. Carrier, "Estimation-Based Synthesis of $\mathcal{H}_\infty$ Optimal Adaptive FIR Filters for Filtered-LMS Problems," *IEEE Transactions on Signal Processing*, Vol. 49, No. 1, Jan. 2001, pp. 164–178. **

2.24 B. Woodley, How, J. P. and R. L. Kosut "Subspace Based Direct Adaptive $\mathcal{H}_\infty$ Control," *International Journal of Adaptive Control and Signal Processing*, Vol. 15, pp. 535–561, Sept. 2001. **

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3.137 M. Alighanbari, L. Bertuccelli, and J. P. How, “Filtered UAV Task Assignment Algorithms for Noisy Environments,” *AIAA Guidance, Navigation and Control Conference*, Aug 2004. AIAA-2004-5251. **

3.138 J. P. How, E. King, Y. Kuwata, “Flight Demonstrations of Cooperative Control for UAV Teams,” proceedings of AIAA 3rd *Unmanned Unlimited” Technical Conference, Workshop and Exhibit,* Sept. 2004. **Best Presentation in Session Award.** **

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3.141 L. Bertuccelli, M. Alighanbari, J. P. How, "Robust planning for coupled, cooperative UAV missions," Proceedings of the IEEE *Conference on Decision and Control* , 2004, pp. 2917–2923. **

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3.164 A. Richards and J. P. How, "Robust Stable Model Predictive Control with Constraint Tightening" proceedings of the IEEE *American Control Conference*, June 2006. **

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3.166 L. S. Breger, J. P. How, and K. T. Alfriend, "Partial J2-Invariance for Spacecraft Formations," to appear at the AIAA Guidance, Navigation and Control Conference, Aug. 2006. **

3.167 M. Alighanbari and J. P. How, "Robust Decentralized Task Assignment for Cooperative UAVs," to appear at the AIAA *Guidance, Navigation and Control Conference,* Aug. 2006. AIAA-2006-6454 **

3.168 G. Tournier, M. Valenti, J. P. How and E. Feron, "Estimation and Control of a Quadrotor Vehicle Using Monocular Vision and Moire Patterns," to appear at the AIAA *Guidance, Navigation and Control Conference,* Aug. 2006. **

3.169 M. Valenti, B. Bethke, G. Fiore, J. P. How, and E. Feron, "Indoor Multi-Vehicle Flight Testbed for Fault Detection, Isolation, and Recovery," to appear at the AIAA *Guidance, Navigation and Control Conference,* Aug. 2006. **

3.170 L. F. Bertuccelli and J. P. How, "Bayesian Forecasting in Multivehicle Search Operations," to appear at the AIAA *Guidance, Navigation and Control Conference,* Aug. 2006. AIAA-2006-6460 **

3.171 L. F. Bertuccelli and J. P. How, "UAV Search for Dynamic Targets with Uncertain Motion Models," to appear at the IEEE *Conference on Decision and Control*, Dec. 2006. **

3.172 Y. Kuwata and J. P. How, "Decentralized Cooperative Trajectory Optimization for UAVs with Coupling Constraints," to appear at the IEEE *Conference on Decision and Control*, Dec. 2006. **

3.173 M. Alighanbari, L. F. Bertuccelli and J. P. How, "A Robust Approach to the UAV Task Assignment Problem," to appear at the IEEE *Conference on Decision and Control*, Dec. 2006. **

4. Other Major Publications

Book Chapters

4.1 T. Pare, H. Hindi, and J. P. How, "Robust Control Design for Systems with Saturating Nonlinearities," Chapter 7, pp. 163–184, in *Actuator Saturation Control,* published by Marcel Dekker, Inc., Editors Kapila and Grigoriadis, 2002. (ISBN: 0824707516) **

4.2 L. Rodrigues and J. P. How, "Towards Unified Controller Synthesis for Hybrid Systems: State Feedback of Sequential Systems," *Advances in Dynamics, Instrumentation and Control,* editors C.-Y. Su, S. Rakheja E. Wang and R. B. Bhat, World Scientific Press, Oct. 2004, pp. 298-311 (ISBN: 9812560866). **

4.3 L. Breger, G. Inalhan, M. Tillerson, and J. How, "Cooperative Spacecraft Formation Flying Model Predictive Control with Open- and Closed-Loop Robustness," to appear in *Recent Advances in Astrodynamics*, Editor P. Gurfil, Elsevier, 2006. **

Journal – Submitted/In Revision

4.4 A. Richards and J. P. How, "Robust Model Predictive Control Using Generalized Constraint Tightening," in revision for the IEEE *Transactions on Automatic Control*, Nov. 2005. **

4.5 M. Alighanbari and J. P. How, "An Unbiased Kalman Consensus Algorithm," submitted to IEEE *Transactions on Automatic Control*, Feb. 2006. **

4.6 L. F. Bertuccelli, M. Alighanbari, J. P. How, "A Robust Approach to the UAV Task Assignment Problem," submitted to the *International Journal of Robust and Nonlinear Control*, May 2006. **

4.7 Y. Kuwata, A. Richards, T. Schouwenaars, and J. P. How, "Distributed Robust Receding Horizon Control for Multi-vehicle Guidance," submitted to the IEEE *Transactions on Control System Technology*, April 2006. **

4.8 A. Richards and J. P. How, "Robust Decentralized Model Predictive Control," submitted to the *International Journal of Control* July 2006. **

Conference – Submitted

4.9 None.

Articles

4.10 J. Leitner, F. Bauer, D. Folta, R. Carpenter, M. Moreau, and J. P. How, "Formation Flight in Space," *GPS World*, Feb. 2002, pp. 22–31.

Manuscripts in Preparation

4.11 T. Schouwenaars, J. P. How, and E. Feron, "Receding Horizon Path Planning with Hard Safety Guarantees," to be submitted to IEEE *Transactions on Automatic Control,* Aug 2006. **

5. **Internal Memoranda and Progress Reports:**

5.1 J. P. How, *A Computer Simulation of Helicopter Flight,* B.A.Sc. Thesis, Department of Engineering, University of Toronto, April, 1987.

5.2 A. Berlin, H. Abelson, N. Cohen, L. Fogel, C.-M. Ho, M. Horowitz, J. P. How, T. Knight, R. Newton, K. Pister, *Distributed Information Systems for MEMS*, ARPA Information Science and Technology Study Group, 1995

5.3 D. Miller, Crawley, E. F., J. P. How, K. Liu, Campbell, M., Grocott, S. C., Glaese, R. M., and Tuttle, T., "The Middeck Active Control Experiment (MACE): Summary Report", MIT SERC report #7–96, June 1996.

5.4 DeBra, D. and J. P. How, "Strategies for Vibration Isolation and Alignment," Proc. of the *Aspen Winter Conf. on Gravitational Waves and Their Detection,* Aspen, CO, Jan, 1997.

5.5 Olsen, E., Park, C. and J. P. How, "A GPS Testbed for Multi-vehicle Control," Draper Final Technical Report (Project #909), June 1998.

5.6 J. Giaime, B. Lantz, S. Richman, D. Debra, C. Hardham, J. P. How, and W. Hua, "Baseline LIGO-II implementation design description of the stiff active seismic isolation system for LIGO-II," March 8, 2000. Version 1.0 LIGO-T000024-00-U

5.7 J. Giaime, B. Lantz, C. Hardham, W. Hua, R. Adhi kari, D. Debra, G. Hammond, J. Hammond, J. How, S. Richman, J.Rollins,G. Stapfer, R. Stebbins, "Advanced LIGO Seismic Isolation System Conceptual Design," Jan. 20, 2001. LIGO-E010016-00-D

6. **Selected Outreach:**

- "Follow my leader", Catherine Zandonella, New Scientist, 25 September 1999, pg. 32.
- "Keeping large structures stable in space, David Salisbury, Stanford Report, September 24, 1997.
- Video Segment on "Tomorrow's World" aired on BBC March 29, 2000.
- Video Segment on "Quantum" aired on the Australian Broadcasting Company, 2000.
- "MIT team guides airplane remotely using spoken English," L. Clark, *MIT Tech Talk* (Vol 49, No. 8), 2004. Also featured in the SpaceDaily (Nov, 2004), SAE *Aerospace Engineering,* December 2004, ABC News (online Nov 17, 2004).

7. **Invited Lectures:**

- May 1995, "Flight Results from the Middeck Active Control Experiment (MACE)" at the Georgia Institute of Technology (Mechanical Engineering).
- "Autonomous Formation Flying using a Carrier-Phase Differential GPS Sensor"
  - Jan. 1997, NASA GSFC
  - Jan. 1997, NASA Johnson Space Center
- "Guidance, Navigation, and Control using Carrier-Differential GPS Sensors,"
  - March 1998, UC Berkeley
  - April 1998, University of Washington,
- April 1999, "Sensing and Control of Formation Flying Vehicles" University of Calgary.
- May 1998, "Advanced Applications of GPS in Space: Formation Flying" at the Hughes Aerospace Company Seminar Series.
- March 1999, "Control Architecture Design for Autonomous Formation Flying Spacecraft" Honeywell Technology Center, Minneapolis, MN.
- April 1999, "Sensing and Control of Formation Flying Vehicles using GPS" presented at the Honeywell GPS Application Technology Workshop, North Clearwater, Florida.
- Jan. 2000, "GPS Sensing and Control for Formation Flying Spacecraft" Lockheed Seminar Series, Palo Alto, CA.
- March 2001, "Mixed Integer Linear Programming for Trajectory Optimization and Formation Management" at the California Institute of Technology, Pasadena, CA.
- July 2002, "Rapid Planning Algorithms for Cooperating Multi-vehicle Teams" at the Graduate Engineering & Research Center, University of Florida, Shalimar, Florida.
- July 2002, "Scaling of UAV testbeds – How, Why, and When" at the Graduate Engineering & Research Center, University of Florida, Shalimar, Florida.
- "Coordination and Control for Cooperating UAVs"
  - Oct. 2002, Mechanical and Aerospace Eng. Seminar, Princeton University;
  - Nov. 2002, Department of Mechanical Seminar, University of California Berkeley
  - Nov. 2002, California Institute of Technology.
- "Hardware-in-the-loop Experiments of Precise Spacecraft Relative Navigation using Carrier-Phase Differential GPS"
  - Jan. 2003, DLR, Germany
  - Jan. 2003, *Int. Conf. on New Trends in Astrodynamics*, Univ. of Maryland,
- Jan. 2003, "Relative Navigation Using GPS for the Orion Formation Flying Mission," at the University of Surrey, UK.
- Nov. 2005, "Coordinated Search of Buried Mines," presented to ARA Inc., Vermont.
- "Robust Coordination of Multiple UAVs in Uncertain and Dynamic Environments,"
  - March 2006, University of Boulder, CO.
  - March 2006, Univ. of Illinois at Urbana-Champaign (Coordinated Science Lab.).
  - March 2006, Duke University.
  - June 2006, Honeywell Technology Center,Minneapolis, MN.

Theses Supervised by Jonathan P. How

Summary

Degree	Total	Completed	In Progress
Bachelor's	1	1	0
Master's	25	20	5
Engineer's	5	4	1
Doctoral			
as Supervisor	27	20	7
as Reader	21	17	4

Bachelor's Theses

1. Erica Peterson, *High Precision GPS Racing Applications,* Final Report for 16.621/16.622 Project, May 2001.

Master's Theses

1. Simon Grocott, *Comparison of Robust Control Techniques for Uncertain Structural Systems* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, Jan. 1994. (co-supervisor with Prof. Miller).
2. Mike Tillerson, *Coordination and Control of Multiple Spacecraft using Convex Optimization Techniques,* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, Jun. 2002.
3. Arthur Richards, *Trajectory Optimization using Mixed-Integer Linear Programming,* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, Jun. 2002.
4. John S. Bellingham, *Coordination and Control of UAV Fleets using Mixed-Integer Linear Programming,* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, Aug. 2002.
5. Nicholas A. Pohlman, *Estimation and Control of a Multi-Vehicle Testbed Using GPS Doppler Sensing,* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, Aug. 2002.
6. Philip Ferguson, *Distributed Estimation for Fleets with Local Ranging,* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, Jan. 2003.
7. Yoshiaki Kuwata, *Real-time Trajectory Design for Unmanned Aerial Vehicles using Receding Horizon Control,* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, June 2003.
8. Trent Yang, *Fault Detection and Isolation Algorithms for Formation Flying Spacecraft,* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, June 2003.
9. Kim Clarke, *Performance Optimization Study of a Common Aero Vehicle Using a Legendre Pseudospectral Method,* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, June 2003.
10. Louis Breger, *Distributed Control of Formation Flying Spacecraft Built on ObjectAgent,* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, Aug. 2004.

11. Megan Mitchell, *Fleet Relative Navigation Using GPS: Theory and Experiments,* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, May 2004.
12. Ellis King, *Demonstration of Distributed Coordination and Control on a multi-UAV Testbed,* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, Aug. 2004.
13. Luca Bertuccelli, *Cooperative Mapping Algorithms for a Fleet of UAVs,* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, June 2004.
14. Mehdi Alighanbari, *Task Assignment Algorithms for Teams of UAVs in Dynamic Environments,* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, June 2004.
15. Chung Tin, *Robust Multi-UAV Planning in Dynamic and Uncertain Environments,* S.M. Thesis, Dept. of Mechanical Engineering, MIT, Aug. 2004.
16. Ian Garcia, *Combined Attitude and Trajectory Optimization to Reconfigure Fleets of Spacecraft,* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, June 2005.
17. Thomas Chabot, *Integrated navigation Solutions for Mars Rovers,* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, June 2005.
18. Henry de Plinval, *Distributed Navigation Algorithms,* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, Jan. 2006.
19. Drew R. Barker, *Attitude Planning Algorithms for Target Tracking using Multiple Spacecraft* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, June 2006.
20. Milan Mandic, *Experimental Demonstration of Distributed Navigation Algorithms on SPHEREs,* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, June 2006.
21. Kieran Culligan *Nap of the Earth Trajectory Design using MILP,* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, expected Aug. 2006.
22. Brett Bethke, *Swarming Control for Multi-UAV Applications* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, expected June 2007.
23. John Griffith, *Attitude and Path Planning Algorithms for Target Tracking using Multiple Spacecraft* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, expected June 2007.
24. Georges S. Aoude *Demonstration of Combined Attitude and Trajectory Optimization on SPHEREs,* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, expected June 2007.
25. Gaston Fiore *Aggressive Maneuver Control using the MIT Quadrotor Testbed,* S.M. Thesis, Dept. of Aeronautics and Astronautics, MIT, expected June 2008.

Engineer's Theses

1. H. Bae, *Active Vibration Isolation Design for LIGO*, Aug 1999 (Mechanical Engineering Dept., Stanford Univ.)
2. J. A. Kaptuch, *Skymark Selection Algorithm for a Space-Based Navigational Concept* Master of Engineering Thesis, Dept. of Aeronautics and Astronautics, MIT, Sept. 2002
3. C. Sae-Hau *Avionics and Software for a Distributed Multi-rover Testbed*, EE, MIT, Sept. 2003
4. Michael J. Matczynski, *Avionics and Software for a Distributed Multi-UAV Testbed*, EE, MIT, June 2006

5. Dan Dale, *Automatic Recharging for a Multi-UAV Testbed*, EE, MIT, expected June 2007

Doctoral Theses, Supervisor

1. E. Teague, *Flexible Structure Estimation and Control using the Global Positioning System,* Ph.D. Thesis, Dept. of Aeronautics and Astro., Stanford Univ., June 1997.
2. H. D. Stevens, *Manipulation of a Free-Floating Object Using A Macro/Mini-Manipulator With Structural Flexibility,* Ph.D. Thesis, Dept. of Aeronautics and Astronautics, Stanford Univ., July 1997.
3. D. Banjerdpongchai *Parametric Robust Controller Synthesis Using Linear Matrix Inequalities,* Ph. D. Thesis, Dept. of Electrical Engineering, Stanford Univ., Oct 1998.
4. S. Lim, *Analysis and Control of Linear Parameter-varying Systems,* Ph.D. Thesis, Dept. of Aeronautics and Astronautics, Stanford Univ., Jan 1999.
5. B. Sayyarrodsari, *An Estimation-Based Approach to the Design of Adaptive Filters,* Ph. D. Thesis, Dept. of Electrical Engineering, Stanford Univ., July, 1999.
6. J. C. Adams, *Robust GPS Attitude Determination in Space using Non-aligned Antenna Arrays*, Ph. D. Thesis, Dept. of Aeronautics and Astro., Stanford Univ., Dec. 1999.
7. E. Olsen, *3D Formation Flight using Differential Carrier-phase GPS Sensors*, Ph.D. Thesis, Dept. of Aeronautics and Astronautics, Stanford Univ., Dec. 1999.
8. T. Corazzini, *Onboard Pseudolite Augmentation For Spacecraft Formation Flying,* Ph.D. Thesis, Dept. of Aeronautics and Astronautics, Stanford Univ., Aug. 2000.
9. T. Pare, *Analysis and Control Design for Systems with Multiple Hysteresis Nonlinearities,* Ph.D. Thesis, Mechanical Engineering Dept., Stanford University, Dec. 2000.
10. H. Schubert, *Impedance Control of Flexible Macro/Mini Manipulators,* Ph.D. Thesis, Dept. of Aeronautics and Astronautics, Stanford Univ. Dec. 2000.
11. A. Hassibi, *Lyapunov Functionals for Hybrid Dynamical Systems*, Ph.D. Thesis, Dept. of Electrical Engineering, Stanford Univ. (co-supervisor with Prof. Boyd), Dec. 2000.
12. B. Woodley, *Model Free Subspace Based $\mathcal{H}_\infty$ Control*, Ph.D. Thesis, Dept. of Electrical Engineering, Stanford University, Jan. 2001.
13. A. Robertson, *Control System Design for Formation Flying Spacecraft: Theory and Experiment*, Ph.D. Thesis, Dept. of Aeronautics and Astro., Stanford Univ., June 2001.
14. C.-W. Park, *Precision Relative Navigation using Augmented CDGPS,* Ph.D. Thesis, Dept. of Mechanical Engineering, Stanford University, June 2001.
15. L. Rodrigues, *Dynamic Output Feedback Synthesis of Piece-wise Affine Systems*, Ph.D. Thesis, Dept. of Aeronautics and Astronautics, Stanford Univ. June 2002.
16. F. Busse, *Precise Decentralized Relative Navigation for formation flying spacecraft in LEO*, Ph.D. Thesis, Dept. of Aeronautics and Astronautics, Stanford Univ. Jan. 2003.
17. K. Sigurd, *Reconfiguration Control in Adaptive Networks* Ph.D. Dept. of Electrical Engineering and Computer Science, MIT, June 2003 (Co-supervisor with Prof. Mitter).
18. E. Prigge, *An Indoor Absolute Positioning System with No Line-of-Sight Restrictions and Building-Wide Coverage*, Department of Aeronautics and Astronautics, Stanford University, Dec. 2004.

19. A. Richards, *Robust Constrained Model Predictive Control,* Ph.D. Thesis from the Department of Aeronautics and Astronautics, MIT, December 2004.
20. T. Schouwenaars *Receding Horizon Control of UAVs with safety Constraints* Ph.D. Thesis from the Department of Aeronautics and Astronautics, MIT, Jan. 2006. (co-supervisor with Prof. Feron)

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21. Y. Kuwata, *Stochastic Trajectory Design and Optimization,* anticipated graduation from MIT in Aug. 2006.
22. L. Bertuccelli, *Cooperative Mapping using UAV Teams,* anticipated graduation from MIT in Dec. 2006.
23. M. Alighanbari, *Distributed Task Assignment Algorithms,* anticipated graduation from MIT in Dec. 2006.
24. M. Valenti *Health Management for UAV Swarms* (Ph.D. Thesis MIT) anticipated May 2007.
25. L. Breger, *Planning for Formation Flying Spacecraft,* anticipated graduation from MIT in Aug. 2007.
26. H.-L. Choi, *Coordinated Control of Multiple Mobile Observing Platforms for Weather Forecast Improvement* anticipated graduation from MIT in Aug. 2008.
27. J. Teo *Decentralized Trajectory Optimization* anticipated graduation from MIT in Aug. 2008.
28. E. Crapero, *Distributed Sensing and Decision Making,* anticipated graduation from MIT in Dec. 2007.

Doctoral Theses, Reader

1. K. Zimmerman, *Experiments in the use of the Global Positioning System for Space vehicle rendezvous*, Dec 1996 (Ph.D. Dept. of Aero. and Astro., Stanford Univ.).
2. K. Neighbors, *Partitioned Systems: Subsystem Specifications for Performance*, March 1996 (Ph.D. Thesis, Dept. of Aeronautics and Astronautics, Stanford Univ.).
3. G. Lightsey, *Development and Flight Demonstration of a GPS receiver for Space*, Feb 1997 (Ph.D. Thesis, Dept. of Aeronautics and Astronautics, Stanford Univ.).
4. D. Miles, *Real-time dynamics trajectory optimization with application to free-flying robots,* Dec 1997 (Ph.D. Dept. of Aeronautics and Astronautics, Stanford Univ.).
5. B. Halder, *Design of Optimal Mixed H_2/H_∞ Controllers*, June 1998 (Ph.D. Thesis, Dept. of Electrical Engineering, Stanford Univ.).
6. J. McNames, *Innovations in Local Modeling for Time Series Prediction*, June 1999 (Ph.D. Thesis, Dept. of Electrical Engineering, Stanford Univ.).
7. M. Trentini, *Multiobjective Helicopter Flight Control,* May 1999 (Ph.D. Thesis, Dept. of Aerospace Engineering, Univ. of Calgary).
8. S. Breneman, *Active Control of Seismic Disturbances in Civil Structures*, Aug 1999 (Ph.D. Thesis, Dept. of Civil Engineering, Stanford Univ.).
9. H. A Hindi, *Local Analysis of Perturbed Linear Systems with Application to Saturating Control Systems,* (Ph.D. Thesis, Dept. of Electrical Eng., Stanford Univ.). Dec 1999.

10. P.-Y. Ko *Analytical and Experimental Observations of Ionospheric and Tropospheric Decorrelation Effects for Differential Satellite Navigation during Precision Approach,* (Ph.D. Thesis, Dept. of Aeronautics and Astronautics, Stanford Univ.). March 2000.
11. D. Dai *Interoperability of Space Based Augmentation Systems for Aircraft Navigation* (Ph.D. Dept. of Aeronautics and Astronautics, Stanford Univ.). June 2000.
12. Song, Kyung Yeol, *Active Control of Radiated Noise from a Cylindrical Shell Using External Piezoelectric Actuators*, (Ph.D. Thesis MIT) June 2002.
13. R. Bester, *Line of Sight Stabilization of an Optical Instrument using Gained Magnetostrictive Actuators* (Ph.D. Thesis - University of South Africa), Aug. 2002
14. Kuo-Chia (Alice) Liu, *Stochastic Performance Analysis and Staged Control System Designs for Space Based Interferometers* (Ph.D. Thesis MIT) June 2003.
15. Sanghyuk Park *Guidance and Control methods for Formation Flight* (Ph.D. Thesis MIT) June 2004.
16. D. Benson, *Direct Optimal Control with Integral Dynamics* (Ph.D. Thesis MIT) June 2005.
17. Laila Elias, *Dynamics of Multi-Body Space Interferometers Including Reaction Wheel Gyroscopic Stiffening Effects: Structurally Connected and Electromagnetic Formation Flying Architectures* (Ph.D. Thesis MIT) June 2004.

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18. Mark Hilstad, *System Identification for Spacecraft Formations* (Ph.D. Thesis MIT) anticipated Dec. 2006.
19. Simone Nolet, *Control Design for Spacecraft Formations* (Ph.D. Thesis MIT) anticipated Dec. 2006.
20. Umair Ahsun *Dynamics and Control of Electromagnetic Satellite Formations* (Ph.D. Thesis MIT) anticipated Dec. 2006.

Post-Docs Supervised

1. Chan-Woo Park 2001
2. Gokhan Inalhan, 2004–2005